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Botany Department.

The Yellow Berry Problem in Kansas Hard Winter Wheats.

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Bulletin No. 156—October, 1908.

Botany Department.

H. F. ROBERTS, M. S., Botanist.
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The Yellow Berry Problem in Kansas Hard Winter Wheats.

PART I.

ONE of the most serious problems which the wheat-growers of the Kansas hard wheat districts have to contend with is that of the so-called "yellow berry." The wheat of this region produces normally a hard, flinty, translucent grain, of medium size and of a clear dark reddish-amber color. By the term "yellow berry" is meant the appearance, in wheat of the above description, of grains of a light yellow color, opaque, soft and starchy. These opaque yellow grains, constituting what are called the "yellow berries," may have this character throughout; but sometimes from a small fraction to half of a grain will be yellow and starchy, while the remainder of the kernel will be hard, flinty and translucent. The difference in color between the flinty grains and the "yellow berries" is due to difference in the structure and contents of the cells of the endosperm.

According to Hackel,[1] if the albuminoids so fill up the intervals between the starch grains that the latter seem to be imbedded in cement, the albumen appears translucent, and the fruit is called "corneous"; but if the union is less intimate there remain numerous small air-cavities, the albumen is opaque, and the fruit is mealy.

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[1] E. Hackel, "The True Grasses," p. 26.

Lyon and Keyser,[2] as the result of their studies on the internal structure of the wheat kernel, say (p. 35):

> "The protoplasmic network of the cells in the sections from the very horny kernels showed only an occasional vacuole; sections from the markedly yellow kernels showed very much more numerous and larger vacuoles, measuring on the average less than 0.001 millimeter. Medium yellow berry kernels had fewer and smaller vacuoles than the markedly yellow kernels."

These writers also found that in the yellow berries the starch grains in the cells were larger in diameter than in the flinty kernels, although not so large as in the typical starchy wheats. The following table indicates the range:

TABLE I.

VARIETY.	Size of larger starch grains, mm.	Size of smaller starch grains, mm.
Sonora (a soft, starchy wheat).............	0.02817	0.005634
Turkish Red (yellow berry)................	0.01704	0 003081
Turkish Red (flinty kernels)	0.01409	0 002817

This agrees with Cobb, who says[3]: "It is noticeable that when the grain is rich in nitrogenous matter the number of large starch granules is smaller."

The yellow berry may then possibly be regarded as an imperfect product, in which the spaces in the cells which are normally filled with proteids (gluten) contain merely water, which, drying out with the ripening of the kernel, leave air-spaces which are responsible for the opaque appearance of the kernel. In addition to this fact is the further one that per unit of volume of the yellow berry kernel there may be a smaller amount of starch than in the flinty grains, on account of the greater size of the individual starch grains. From the standpoint, therefore, of both gluten and starch, the yellow berry is probably an inferior kernel, and from the economic standpoint it may be regarded as a degenerate product.

It should further be emphasized that the bleached opaque grains, due to weathering, are not "yellow berries." In weathered kernels the grain has an opaque and rather dirty grayish-yellow aspect, which appearance affects the grading of the grain adversely, but is not necessarily associated with an inferior condition of the kernel, although such frequently is the result of exposure to the weather.

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[2] Winter Wheat. T. L. Lyon and A. Keyser, Nebraska Experiment Station, Bull. 89 (June, 1905).

[3] Cobb, N. A., in *Agricultural Gazette*, New South Wales, vol. XV, part 6, p. 512.

This distinction between weathered grains and yellow berry has been dwelt upon, because, to judge from the literature upon the subject, much confusion concerning these characters exists, not only among farmers but also among experiment station men.

The yellow berry, then, appears to be distinctly a physiological growth product, due to certain conditions thus far not clearly analyzed or satisfactorily explained in any of the experiment station publications, and the causes of which have constituted the object of the investigations which this bulletin reports.

PHYSICAL CHARACTERS OF THE YELLOW BERRIES.

In addition to, and in consequence of, the structural characters alluded to, viz., the presence of numerous vacuoles in the endosperm-cells, filled with air, which in the corresponding flinty grains of the same variety are filled with gluten (proteids), there are found to exist some interesting and important conditions with respect to weight and specific gravity. The presence of air-vacuoles doubtless accounts for the lighter weight and the uniformly lower specific gravity of the yellow berry kernels. Owing to the higher specific gravity of the carbohydrates in the wheat kernel (starch 1.53, sugar 1.60, cellulose 1.53), as compared with the proteids (gluten 1.297),[4] it would necessarily follow that the true starchy wheats are the heaviest wheats and possess the highest specific gravity.

TABLE II.*

	Average pounds per bushel.	Average weight of 100 grains.	Average per cent. of carbohydrates, fat and crude fiber.	Average per cent. of nitrogen.
Hard spring, hard winter and semi-hard winter wheat districts	57.1	3.368	75.06	2.01
Soft wheats and Southern wheat districts	57.5	3.433	76.06	1.86
Irrigation and Pacific Coast wheat districts	58.9	4.045	78.03	1.62

* Compiled from reports of the U. S. Dept. of Agriculture.

The degree of correspondence that there may be between the particular kind of starchy grain appearing in hard wheat and known as "yellow berry," and the ordinary soft and starchy wheats proper of the Middle states and the Pacific coast, is not known. So far as the present meager physical data admit of comment, it would appear that the starchy wheats of the Pacific coast, and to a less degree the starchy wheats of the Middle and Southern states, average somewhat higher in pounds per bushel than the hard winter and spring wheats. Whether the data available will be substantiated by more rigid methods of determination is uncertain. Whatever may be true of the soft wheats of the Middle and Southern states in this respect, concerning which there is the most doubt, it certainly appears true that in some parts of California soft, starchy white wheat grows which is heavier in pounds per bushel than the hard winter and spring wheats. (See table II.)

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[4] Körnicke und Werner, Handbuch des Getreidebaues, vol. 2, p. 120 (1884).

Now the yellow berry does not resemble this type of soft wheat in respect to weight, since the yellow berries, in weight and in specific gravity, fall below the flinty kernels of the same variety. The question therefore remains open, to what extent the yellow berry is a varietal trait, and to what extent merely a condition brought about by seasonal influences, whereby it can be considered a degeneration product, containing not only, as is known, less protein than the flinty kernels, but also less starch per unit of volume. This latter point is an interesting and critical one, upon which the writers are now working. There are data on hand which support both views of the nature of the yellow berry, but they are too incomplete to warrant any statement whatever at the present time.

The essential thing, from the practical standpoint, is to discover whether pure stocks of wheat can be found which produce constantly a minimum amount of yellow berry in the hard wheat region in seasons and localities in which the yellow berry ordinarily occurs.

In twenty-one varieties investigated for yellow berry at this Station by the Botanical Department, the results, with respect to weight and specific gravity, are shown in table III.

The data embodied in this table were obtained as follows: The weight and volume were determined for 200-grain lots each of yellow berry and of flinty kernels, taken from the same variety; and this for each of the twenty-one sorts of wheat. The volume was determined by the amount of 95 per cent. alcohol displaced by 200 grains in a 50 cc. specific-gravity

TABLE III.

NUMBER.	Average weight, gms.		Specific gravity.	
	Yellow berry (100 grains).	Flinty kernels (100 grains).	Yellow berries.	Flinty grains.
1	2.767	2.824	1.306	1.356
2	2.543	2.546	1.320	1.337
3	2.616	2.636	1.318	1.368
4	2.614	2.762	1.331	1.353
5	2.720	2.582	1.299	1.348
6	2.616	2.729	1.309	1.389
7	2.721	2.891	1.319	1.341
8	2.483	2.555	1.302	1.328
9	2.846	3.167	1.311	1.343
10	2.710	2.664	1.311	1.319
11	3.384	3.492	1.273	1.327
12	2.881	2.995	1.273	1.312
13	2.735	3.273	1.268	1.317
14	2.246	2.818	1.254	1.304
15	2.749	3.034	1.291	1.310
16	2.398	2.429	1.307	1.328
17	2.041	2.225	1.307	1.315
18	2.002	2.149	1.316	1.322
19	2.464	2.647	1.314	1.354
20	2.584	2.732	1.322	1.337
21	2.405	2.395	1.333	1.346
Averages	2.596	2.740	1.304	1.336

bottle. From the table above, it is seen that the average weight of the yellow berries per hundred was 2.596 grams, as against 2.740 grams for the hard, flinty grains. There were, however, three cases in which the absolute weight of the yellow berries was greater.

For the specific gravity there were no exceptions to the rule that the flinty grains have a higher specific gravity than the yellow berry grains of the same variety. In the above-mentioned twenty-one sorts, where the average specific gravity of the yellow berries was 1.304 while that of the flinty grains was 1.336, there can be no escaping the conclusion that the yellow berries, in all probability, owe this lesser specific gravity largely to the presence of numerous air-cavities, although to what an extent an actual diminution of the carbohydrates and the inorganic salts of high specific gravity may accompany this is not known. The actual loss of protein involved in the production of yellow berries may be gathered from table IV, taken from bulletin 89 of the Nebraska Experiment Station, to which reference has already been made.

TABLE IV,

Bull. 89, Neb. Exp. Sta., p. 30 (1905).

No.	Description.	Nitrogen.
40......	Horny red (lightest light), 1901......	2.23%
41.......	Yellow berry (lightest light), 1901......	1.83
42.......	Horny red (heaviest heavy), 1901......	2.32
43.......	Yellow berry (heaviest heavy), 1901......	1.70
44.......	Horny red (lightest light), 1902......	3.20
45.......	Yellow berry (lightest light), 1902......	3.10
46.......	Horny red (heaviest heavy) 1902......	3.40
47.	Yellow berry (heaviest heavy), 1902......	2.90

Average for Horny red, 2.79 per cent.; average for yellow berry, 2.38 per cent.

Now it is a clearly defined fact that loss of protein (gluten) content in the wheat grains means diminution in flour-making value; and the fact that grain inspectors reduce the grade of a hard wheat containing yellow berry is practical evidence to this point.

Snyder[5] explains the matter as follows:

> "It is generally considered that the more amber and glutenous wheats yield a higher percentage of the patent flours and less of the clear and lower grades, while the lighter-colored or starchy wheats show a tendency to produce a higher percentage of total flour, but less is recovered as patent graded. . . . These physical characteristics are closely associated with, and dependent upon, chemical composition. . . . When two types of seed, light and dark, were selected from the same lot of wheat, the darker seeds in all samples analyzed were found to be richer in protein. . . . This difference is observed in illustration No. 120, showing the flinty character of the dark-colored grains and the starchy nature of the light-colored ones."

IMPORTANCE OF THE YELLOW BERRY PROBLEM.

Because of the fact that in central and northern Kansas is produced the best milling wheat in the United States, on account of the very high per cent. of a gluten of excellent quality and texture which this wheat yields in the flour, any factor that brings about deterioration in the grade of this wheat calls for serious investigation.

As has been shown, the yellow berry is such a factor, inferior certainly in protein content and probably also in starch; lower in specific gravity and generally also in absolute weight per bushel. The presence of the yellow berry in any quantity in our hard wheat affects unfavorably its commercial grading and its market price. It therefore seems to the writers that the yellow berry problem is one of first importance in connection with wheat-breeding; since if by any means wheat races can be produced in which the physical changes resulting in the yellow berry type of kernel will not take place under any conditions, the value of such races will be inestimable to this state and to the hard winter wheat district in general.

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[5] Harry Snyder, Bull. 90, Minn. Exp. Sta. (Jan., 1905), pp. 83-185.

THE INFLUENCE OF CLIMATE.

It has long been known that in cool, moist climates, such as the maritime regions of Western Europe and of our north Pacific coast, the wheats there grown have larger grains, are softer, and lower in percentage of proteid nitrogen than the wheats grown in the continental areas, such as the interior of Russia, the Balkan states, Hungary and the central western states in this country.

Schindler,[6] the most extensive investigator hitherto of the relation of wheat to climatic factors, says, page 75:

> "With the length of the vegetative period, especially with the extent of the interval between blossoming and ripening, not only the dimensions of the kernel increase, but also the quantity of the carbohydrates stored therein, while the protein content diminishes."

Again, page 32:

> "It is not justifiable to speak of the size of the kernel and the protein content of the berry as 'race characters.' They may be such to a certain limited extent, but the influence of the race will in this connection be far exceeded by the influence of climate, and partly also by that of soil and cultivation. . . . The mode and the abundance of deposit of starch in the endosperm depends possibly upon the climate or upon the weather phenomena, as the case may be, especially during the period of the 'milk.' In regions with moist warm climates and a long vegetative period, the interval from fertilization to maturity is likewise a long one, and during this period abundant quantities of starch can be formed in the large leaf surfaces which the wheat endemic to such a climate is apt to produce, and which, in the course of the slow development of the grain, can be completely transported thither. Externally, the extensive storage of starch is indicated in the broad form of the kernel. The protein content is diminished when wheat native to such a climate is transported to a hotter, dryer region. At a time when, in its native home, it continued undisturbed in the transportation of starch formed in the leaves to the ovary, here lack of water and high temperature combine to bring the growth to a close prematurely. The time is accordingly shortened for the passage of starch into the kernels, and even though the intensity of assimilation in warmer regions be greater, yet, on account of the time limitations, this factor cannot wait for a variety which is not adapted to a more rapid development. . . . From these considerations it un-

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[6] Franz Schindler, "Der Weizen," Berlin, 1895.

disputably follows that, even in one and the same locality, and with the same variety, the relation between protein and starch must be a variable one, according to the weather conditions; even though it is to be admitted that individual sorts or races, as the case may be, may possess for themselves an especially different energy of assimilation. It is certain, however, that this latter, in its final effect, stands far behind that of climate and of the weather."

We have quoted thus extensively from Schindler's work, because, with one or two exceptions, it is practically the only study of the wheat question that deals with the problems in at all a fundamental way.

It has long been known among scientific agronomists that regions characterized by a hot, dry climate of limited rainfall, and in which the final maturing of the wheat hastens fast upon the blossoming, are the regions in which the wheat grain is hardest and highest in protein content. Such regions are the "black soil" district of Russia, much of the Mediterranean coast region, the table-lands of Hungary, and the central and northern plains region of the United States.

It is, moreover, well known that seasonal differences in the same region bring about marked changes; that a hot, dry growing season results in a lower yield of wheat, which is harder and of higher protein content; while a moist, cool growing season results in the production of larger, softer grains of lower protein content.

So much for the general phenomenon. However, the yellow berry problem is not solved by reference to the above conditions. As has been said, the yellow berry is not simply a special phase of the general phenomenon of a relatively greater proportion of starch to protein deposited in the grain in consequence of a longer growing season. It is a case not merely of failure to form the normal amount of gluten *but probably also of a corresponding failure on the part of the plant to compensate by a relative increase in the starch content.*

The yellow berry problem is therefore a decidedly special one. Since the climatic factors are, above all others, prominent in determining the composition of the wheat grain, it remains to search out the critical period in the plant's life-history when its susceptibility to the formation of the yellow berry is greatest, and to ascertain what relation the climatic or seasonal factors may have thereto. It is clear that such knowledge will suggest means for avoiding the economic loss involved in the production of the yellow berry.

NATURE OF THE EXPERIMENTS.

In order to throw more light on this phase of the subject, it was determined to discover, if possible, the relation between the amount of yellow berry produced and the climatic conditions for the growing season concerned. During the years 1906-'07, 128 varieties of wheat were grown for the special purpose of investigating the yellow berry problem. For each variety, careful records were kept of the date of planting, the date of coming up, the stand, vigor of the plants, extent of winter-killing, time of first and full heading, date of ripening and date of harvesting. The plots were very closely watched, and each was harvested immediately after it was considered fully ripe. In harvesting, the heads, after being cut off, were put into loose cloth sacks and taken to the laboratory the same day as that on which they were gathered. After drying out thoroughly under cover, the product from each plot was threshed separately with a flail and was carefully winnowed by hand. It is thus seen that each sample of wheat was subjected to exactly the same manipulation and mode of treatment during each of the two years of the experiment. The existence of yellow berry in any of the samples could not, therefore, be attributed either to overripeness or to exposure to the weather after the grain had been cut, but could only be ascribable to the influence of the weather conditions upon the growing or ripening grain or to inherent hereditary tendencies in the varieties themselves, or to both.

Each lot of air-dry grain, after cleaning, was thoroughly mixed, and a representative sample of 100 grains was taken out. Each of these samples was then separated by inspection into two lots, containing the flinty grains and the "yellow berries," respectively. As a criterion for classification, it was determined to consider as the "flinty grains" only those that were of a clear, reddish-amber color *throughout.* If a kernel bore even one or two small opaque starchy spots, it was classified among the "yellow berries."

After separation, the number of grains in each lot were counted, and the percentage of yellow berry recorded. To guard against the influence of the personal equation, and to insure all of the results being comparable with one another, all of the work of separation was done by one person. Further to safeguard the results, the operator was careful not to notice the label borne by any sample until after finishing the separation and counting the grains.

CLIMATOLOGICAL DATA.

These were obtained from the records of the Physics Department. The data are derived from self-registering instruments on the college campus, located about one-fourth mile from the wheat-breeding plots of the Department of Botany.

For purposes of comparison, the mean temperatures and precipitation for each month during the wheat vegetative season, and for the two crop years of 1905-'06 and 1906-'07, are given in table V.

TABLE V.

MONTH.	Mean temperature, Fahrenheit.		Precipitation, inches.	
	1905-'06.	1906-'07.	1905-'06.	1906-'07.
September	72.10°	71.88°	4.32	4.62
October	54.20	55.00	2.19	0.88
November	45.60	40.09	3.60	2.18
December	33.15	35.76	0.00	0.64
January	38.82	29.69	0.89	1.38
February	35.65	31.21	1.60	1.62
March	32.80	51.19	2.12	1.37
April	59.60	46.07	2.26	1.30
May	66.74	59.24	2.00	1.10
June	74.60	70.90	6.73	6.07
July	76.13	78.58	5.28	6.46
Averages and totals, excluding July	51.33°	49.10°	25.72	21.11

The wheat varieties included in the experiment were planted from one to nineteen days earlier in the fall of 1906 than in the fall of 1905; and the mean autumn temperature and the amount and distribution of the rainfall were slightly more favorable in 1906. We may therefore reason that the wheats probably entered the spring vegetative period of 1907 in slightly better condition than the spring period of 1906. The early part of March, 1907, was extremely warm, but the subsequent return of cold weather brought the mean temperature of April, May and June much lower than for the corresponding months of 1906.

The general effect of these conditions, and of the respective dates of the planting, upon the length of the spring vegetative period and the percentage of yellow berry, may be seen in the following table:

TABLE VI.

	1906.	1907.	Differences.
Number days from planting to January 1	90	95	5
Number days from March 1 till ripe	118	125	7
Average total vegetative season, days	267	279	12
Average per cent. of yellow berry	33	39	6

INFLUENCE OF INDIVIDUAL CLIMATIC FACTORS; CRITICAL PERIODS.

In endeavoring to analyze individually the influence of each of the chief climatic factors—temperature, light, air movements and precipitation—in relation to the growth of the wheat plant, and especially in endeavoring to ascertain the share of each factor in determining the changes resulting in the "yellow berry," we find that we are dealing with problems of the most extreme complexity and intricacy. Only by means of adequate meteorological apparatus, by the preservation of full and accurate records, by using a large number of varieties, and by the extension of the experiments over a number of years, can we expect to overcome the influence of special conditions and obtain representative averages.

So far as our investigation is concerned, while it covers but two years of experimental work, and while, by increase in the range of the meteorological data, and especially by the extension of the experiments over a number of years, the writers hope to obtain more satisfactory averages, yet the results thus far are so striking and significant in certain features that in our judgment they merit publication as far as completed.

It should, however, be realized that the results thus far obtained must of necessity be treated as qualitative rather than quantitative, and as preparing the way for the more detailed quantitative researches which are to follow. This bulletin therefore stands as a preliminary report of the work in progress, and not as a final announcement of ultimate results.

RELATION BETWEEN DATE OF PLANTING, AUTUMN VEGETATIVE CONDITIONS AND THE PERCENTAGES OF YELLOW BERRY.

For the purposes of this investigation, the autumn vegetative period is taken, roughly, to extend from the date of planting to January 1. The latter date is arbitrarily selected on account of the fact that in the Kansas hard wheat regions there are frequently rather prolonged warm periods extending through much of November and December, during which time the extent of root growth and the amount of stooling or tillering may be considerable. From January 1 to March 1, however, and frequently later, the wheat usually remains almost entirely dormant.

The differences in the fall vegetative conditions of the wheat in the autumn of 1905, as resulting from differences in the date of planting, and the extension of these effects into the spring of 1906 in respect to the percentage of yellow berry, are indicated in table VII. Here it will be seen that the fall vegetative period varied from ninety-four to seventy-six days for different plots, which involved a variation in the mean temperature for the period of from 45.5° to 41.1° F. The percentages of yellow berry produced from the different plantings are seen, with but one very slight exception, to decrease directly with the decrease in the mean temperature for the fall vegetative period; or, in other words, with the diminution of the sum total of the achieved autumn growth.

TABLE VII. Relation of the date of planting and the duration of the fall vegetative period to the percentages of yellow berry—1905-'06.

Date of planting.	No. of cases.	No. days fall vegetative period.	Mean temperature, deg. F.	Total rainfall, Sep. 1 to Jan. 1, inches.	Rainfall three weeks before planting, inches.	Rainfall three weeks after planting, inches.	Average per cent. of yellow berry.
Sep. 28...	9	94	45.47	10.11	2.19	0.72	53.80*
Sep. 29...	15	93	44.91	10.11	2.19	0.72	45.43*
Sep. 30...	25	92	44.84	10.11	2.21	0.70	27.20*
Oct. 2...	51	90	44.53	10.11	2.04	0.73	35.74*
Oct. 11...	4	81	42.09	10.11	0.35	1.86	22.25†
Oct. 16...	24	76	41.07	10.11	0.73	3.95	19.58†
Averages,	128	89.9	43.98	10.11	1.80	1.36	33.00

* Planted in moist soil; germination rapid.
† Planted in dry soil; germination slow.

So far as the rainfall for the period is concerned, in its effect upon the young plants, the differences in these amounts are small. The plantings from September 28 to October 2, however, went into moist soil, while the plantings of October 11 to 16 were in rather dry soil, with consequent delay of germination and retardation of the initial growth of the seedlings. For the season of 1905-'06, then, it seems that the minimum of yellow berry appeared in the plantings in which there was a minimum opportunity for development in the fall. Just what relation there may exist by way of cause and effect between these two sets of phenomena will appear later.

In table VIII is seen a similar tabulation for the season 1906-'07:

TABLE VIII. Relation of date of planting and duration of the fall vegetative period to the percentages of yellow berry—1906-'07.

Date of planting.	Number of cases.	Number of days in fall vegetative period.	Mean temperature, Fahrenheit.	Total rainfall, Sep. 1 to Jan. 1, inches.	Rainfall three weeks before planting, inches.	Rainfall three weeks after planting, inches.	Average per cent. of yellow berry.
September 26	39	96	44.54°	8.27	4.62	0.45	44.33
" 27	53	95	44.28	8.27	4.62	0.45	37.22
" 28	14	94	44.14	8.27	4.62	0.45	36.16
" 29	22	93	43.98	8.27	4.62	0.45	32.63
Averages	128	94.8	44.30	8.27	4.62	0.45	39.00

A comparison of the data for the two years shows the same diminution in the percentage of the yellow berry with the shortening of the total time of the fall vegetative period, and a corresponding decline in the mean temperature for that period. It must be noted, however, that the planting season of 1905-'06 lasted over nineteen days, corresponding with which there was a decrease in the average amount of yellow berry of from 54 per cent. in the highest to 20 per cent. in the lowest case.

On the other hand, the planting season of 1906-'07 covered a period of but four days, and there was a correspondingly lower range to the average percentage of yellow berry from the different plantings of from 44 per cent. in the highest to 33 per cent. in the lowest case.

The average fall vegetative season of 1905-'06 was five days shorter than that of 1906-'07, and whereas the rainfall was slightly more favorable in the former period the temperature was somewhat higher in the latter. It may therefore fairly be concluded that, disregarding the date of planting, the fall growing season was equally favorable in all respects, except in that of mean temperature, for the two years. It may therefore be assumed that the reduction in the total length of the growing period with the later plantings, the consequent lower mean temperature for the period of fall growth, and the necessarily retarded and diminished development of the plants, is in direct correspondence with the subsequent development of yellow berry in the spring, at least so far as the data for the two years are concerned.

RELATION BETWEEN THE SPRING VEGETATIVE CONDITIONS AND THE PERCENTAGE OF YELLOW BERRY.

The spring vegetative period for wheat in this region is taken to be the time from March 1 to the date of ripening of the grain. By reference to the following table, it will be seen that this period in 1907 was twelve days longer than in 1906, and that this difference was accompanied by an average increase in yellow berry for 1907 of six per cent. over the average for 1906. The extent to which the lengthening of the spring vegetative period was due to the later planting in 1907 is shown in table IX, which also shows the relation between the date of planting and the date of ripening:

TABLE IX. Relation of length of spring vegetative period to length of fall vegetative period.

1906.

Length of fall vegetative period, days	94	93	92	90	81	76
Number of cases	9	15	25	47	4	27
Average length of spring vegetative period	110.3	110.5	119.6	119.8	119.0	118.1

1907.

Length of fall vegetative period, days	96	95	94	93		
Number of cases	40	52	14	22		
Average length of spring vegetative period	125.7	124.6	126.7	128.8		

In spite of the fact, previously mentioned, that the fall seasons of 1905-'06 and 1906-'07 were equally favorable, except for the disadvantages entailed by different dates of planting, it is seen nevertheless that plantings of the same date in the two years did not mature in equal periods, but that the spring vegetative period in the latter year was, on the average, sixteen days longer than in the year before for the same period. This fact can only be explained by the differences which might have obtained during the winter or spring. Now, since the wheat plants are practically dormant throughout the winter, it is more than probable that the conditions which, independent of the date of planting, caused the longer spring growing period of 1907, must be sought in the weather conditions between the time of resumption of active growth in the spring and the time of ripening.

By referring to table V, and by considering the spring season as a whole, it will be noted that during March, 1906, the weather was cold, but that with April more favorable weather came, both as to temperature and rainfall, and that these improved conditions prevailed until the time of ripening.

In 1907, on the other hand, March was abnormally warm, which brought about an early rapid growth in the wheat plants. This favorable weather was, however, followed by cold, dry weather in the latter part of March and the early part of April, which moreover persisted throughout April and May. June, the first really favorable month for plant growth, was itself colder than the same month of the previous year. The effect of these conditions as a whole has already been mentioned and is shown in table VI.

It remains to analyze the seasonal conditions in the spring vegetative period in detail, and to discover, if possible, from such evidence, the critical time in the growth of the plants when the influence of the external conditions on the production of yellow berry is most decisive.

Assuming the two weeks preceding ripening as the critical period in question, the mean temperature for the two weeks before ripening of each variety was calculated; the varieties were arranged in groups according to their mean temperatures, and the average percentage of yellow berry in each group was determined:

TABLE X. Relation of mean temperature for two weeks before ripening to percentage of yellow berry.

1906.

	Mean temperature, Fahrenheit.					
	73°	74°	75°	76°	77°	78°
Number of cases	41	20	53	7	0	7
Average per cent. of yellow berry	23	48	35	23	0	32
1907.						
Number of cases	60	28	8	21	0	11
Average per cent. of yellow berry	45	32	25	28	0	47

Total average mean temperature: 1906, 75.06° F.; 1907, 74.84° F.
Total average per cent. of yellow berry: 1906, 33; 1907, 39.

A close scrutiny of the above table does not disclose any definite relationship between the mean temperature for two weeks before ripening and the production of yellow berry. If, therefore, there be any such relationship, it has been obscured, for these two years at least, by other factors. If, however, we make a similar study of the relationship of the mean temperature for three weeks before ripening to the production of yellow berry, we find results which are more uniform:

TABLE XI. Relation of mean temperature for three weeks before ripening to percentage of yellow berry.

1906.

	Mean temperature, Fahrenheit.			
	72.6° to 73.5°	73.6° to 74.5°	74.6° to 75.5°	75.6° to 76.5°
Number of cases	52	40	21	15
Average per cent. of yellow berry	44	25	22	35
1907.				
Number of cases	2	28	82	16
Average per cent. of yellow berry	73	50	32	47

Total average mean temperature: 1906, 74.13° F.; 1907, 75.66°. F
Total average per cent. of yellow berry: 1906, 33; 1907, 39.

Table XI seems to indicate that, in general, higher mean temperatures for three weeks before ripening are correlated with lower percentages of yellow berry, although there are several exceptions.

It will be noted that as the mean temperature rises there is a steady decline in the percentage of yellow berry in both years, until the highest mean temperature is reached (last column); and that here, for both years, the percentage of yellow berry has increased. In this last column fall those wheats which ripen late, after the hot weather of midsummer begins.

A further apparent contradiction to what seems the general rule, as exhibited by table XI, that the higher the mean temperature for the three weeks before ripening the lower the percentage of yellow berry, is seen in the fact that whereas the mean temperature for three weeks before ripening was lower in 1906 and in 1907, yet the higher percentage production of yellow berry was not in the former year, but in the latter.

Although little or no influence in the formation of the yellow berry seemed to be traceable to the mean temperature for the two weeks preceding ripening, yet, when a corresponding period of three weeks was taken, more influence seemed evident. On this account it was decided to trace the possible influence of the mean temperature even farther back from the date of ripening—to the date of the first appearance of the spike. The data were computed in the same manner as for tables X and XI:

TABLE XII. Relation of mean temperature to percentage of yellow berry, from time of first heading to maturity.

Mean temperature, Fahrenheit.	1906.		1907.	
	No. cases....	Av. per cent. yellow berry.	No. cases....	Av. per cent. yellow berry.
68.5° to 68.9°	......	......	1	62.0
69.0 to 69 4	......	......	20	46.0
69.5 to 69.9	......	......	52	40.3
70.0 to 70.4	......	......	17	28.5
70.5 to 70.9	......	......	9	19.6
71 0 to 71.4	......	......	10	42.4
71.5 to 71.9	39	44.7	1	71.0
72.0 to 72.4	40	26 7	0	......
72.5 to 72.9	18	29 0	3	57.0
73.0 to 73 4	30	28.9	5	34.2
73 5 to 73.9	1	0	9	41.4
74.0 to 74.4	......	......	0	......
74 5 to 74 9	......	......	0	......
75.0 to 75.4	......	......	1	6.0

Total average mean temperature: 1906, 72.41° F.; 1907, 70.48° F.
Total average precipitation: 1906, 4.74 in.; 1907, 6.55 in.
Total average per cent. of yellow berry: 1906, 33; 1907, 39.

It will be noted that the results within the individual years are not so uniform here as in the preceding case (table XI), but when the total averages for the two years are compared they harmonize with the theory that high temperatures are correlated with a minimum of yellow berry in the crop.

Taking also into consideration the amount of the rainfall from the sixth day before heading to the fourth day before ripening, no relation becomes apparent between the precipitation and the production of yellow berry.

The data to this point are given in the following table, in which the wheat varieties grown in 1906-'07 are arranged in groups, according to the amount of rainfall occurring within the dates previously mentioned; the average percentage of yellow berry being calculated for each group:

TABLE XIII. Relation of precipitation to percentage of yellow berry.

	Precipitation, inches.				
	1 to 1.9	2 to 2.9	7 to 7.9	8 to 8.9	9 to 9.9
Number of cases...........	31	39	51	5	2
Average per cent. of yellow berry.....................	50.31	23.59	27.94	32.80	59.50

A similar study was not made for the year 1907, for the reason that all of the varieties received very nearly the same amount of precipitation between the growth dates previously mentioned.

RELATION OF THE TIME, FROM FIRST HEADING UNTIL RIPENING, TO THE PRODUCTION OF YELLOW BERRY.

Considering the length of time between the dates of first heading and of ripening, in relation to the production of yellow berry, it is seen that, as between the averages for *different* years, those years in which the ripening was slow produced the greatest percentage of yellow berry. When, however, this principle is sought to be applied to the different rates of ripening discoverable among the many varieties grown during the *same* year, it is found that it does not hold. Indeed, with some exceptions, there seems to be a slight *decrease* in the percentage of yellow berry, corresponding to the increase in the number of days between the first heading and the ripening of the varieties:

TABLE XIV. Relation between the number of days from first heading to ripening and the production of yellow berry.

1906.

	Number of days from date of first heading to ripening.							
	29 to 31	32 to 34	35 to 37	38 to 40	41 to 43	44 to 46	47 to 49	50 to 52
Number of cases.......	1	30	34	28	27	6	0	2
Average per cent. of yellow berry..........	23	46	26	26	34	25	......	60
1907.								
Number of cases.......	1	1	6	28	69	16	5	2
Average per cent. of yellow berry..........	6	51	48	42	39	23	45	42

Total average number of days: 1906, 38; 1907, 42.
Total average per cent. of yellow berry: 1906, 33; 1907, 39.

From table XII we may note that the total average mean temperature was about two degrees higher and the rainfall about two inches less in 1906 than in 1907 for the time between first heading and ripening. It is very probable that this might easily account for the fact that the average ripening period was four days shorter in the former year, and might also, at least partially, account for the greater percentage of yellow berry in 1907. The average date of first heading was May 20, in 1906, while in 1907 it was three days later. Since the wheats were planted on an average five days earlier in 1907, we should expect, other things being equal, that the time of first heading would itself be earlier in 1907. Some climatic agency must therefore be sought which would have been able to counteract the effects of late planting in 1906, and which would in addition have been responsible for causing the wheats to come into head three days earlier in 1906 than in 1907. This fact is easily discernable in the sum total of the weather conditions for April and May, which may be briefly summarized as follows:

TABLE XV.

	Precipitation.		Number of cloudy days.		Mean temperature.	
	1906.	1907.	1906.	1907.	1906.	1907.
April	2.76	1.30	13	10	59.60°	46.07°
May	2.00	1.10	14	13	66.70	59.45
Total and averages	4.76	2.50	27	23	63.23	52.87

From this table it becomes clear that the rapidity of growth in general, including the time of coming into head and of reaching final maturity, as well as the percentage of yellow berry produced, are the resultants of at least several combined seasonal factors of which the most important are those which obtain in the spring. The length of time duration for the autumn growth, as determined by the date of planting, and the climatic factors of the fall vegetative period, are merely of underlying importance as deciding the stage of growth and the general condition of the plants on their resumption of activity in the spring. If we attempt to interpret the effect of these combined influences in terms of the rapidity of growth of the plants and of the ripening of the grain, and to correlate them with the percentage production of yellow berry, we shall find, as previously stated, that the prevalent idea that slow ripening is correlated with high percentages of yellow berry is apparently justified by the data collected from our wheat cultures for 1906-'07, *when the total averages for the two years are compared.* (Table XIV.)

When, however, the data for the different varieties *within* a given season are considered, this rule does not hold. (See, also, table XIV.) Now, since it is improbable that influences that would operate as *between* different seasons to bring about such a result would fail to operate *in* a given season, there must therefore be other factors, or combinations of factors, which complicate the results, and which are not analyzable without taking into consideration data with reference not alone to climatological conditions but also to the hereditary tendencies of the varieties concerned.

TABLE XVI. Relation between length of spring vegetative period and the percentage of yellow berry.

1906.

	Number of days from March 1 until ripe.					
	106 to 110	111 to 115	116 to 120	121 to 125	126 to 130	
Average mean temperature, first head until ripe, Fahrenheit,	71.86°	71.97°	72.23°	73.23°	73.25°	
Number of cases..	29	6	58	28	7	
Average per cent. of yellow berry,	51.86	46.33	24.89	24.53	40.43	

1907.

	Number of days from March 1 until ripe.					
	116 to 119	120 to 123	124 to 127	128 to 131	132 to 135	136 to 139
Average mean temperature, first head until ripe, Fahrenheit,	68.78°	69.47°	70.07°	71.66°	72.48°	73.93°
Number of cases..	1	31	64	21	10	1
Average per cent. of yellow berry,	62.00	50.29	35.68	27.90	50.00	21.00

Total average number of days from March 1 to maturity: 1906, 118; 1907, 125.

Total average per cent. of yellow berry: 1906, 33; 1907, 39.

Examination of the data for both years, in table XVI, when taken with reference to the spring growing season, would seem to indicate that those wheats which ripened slowly, and which therefore had a long growing season, have a lower percentage of yellow berry. This is directly contrary to the generally prevalent idea as heretofore expressed, and also to the results obtained from the total averages of the two years, as taken separately.

If, however, we examine the column in table XVI giving the average of the mean temperatures from date of first heading to date of ripening for the different groups, we shall find that the wheats ripening later *ripened under the higher temperatures.* This fact confirms the conclusion previously drawn, and indicates that the later wheats, by the fact that their ripening period is brought over into the warmer season, are thus subjected to temperatures the effect of which appears to be to overcome any effect ascribable to a slow ripening period, with the net result, at any rate, that they have a lower percentage of yellow berry than the wheats ripening earlier.

In the last column for 1906 (table XVI), the next to the last for 1907 in the same table, there appears a group of slow-ripening wheats which, despite the higher mean temperatures prevailing from first heading to ripening, have yet varied from the rule in the production of high percentages of yellow berry. An attempt to explain these apparently anomalous cases will be found in the second part of this bulletin.

PART II.

INDIVIDUAL AND VARIETAL INHERITANCE OF YELLOW BERRY.

One of the most desirable achievements in wheat-breeding would be the origination of a strain of hard glutenous winter wheat which under no conditions would produce grains of the inferior "yellow berry" type. Attempts to secure such strains by importation from the hard wheat districts of Russia, Hungary and the Balkan states have been made. In a way the same end has been sought by the efforts of different breeders to improve the gluten content of wheat by various systems of selection, based upon chemical analyses of the grain and upon milling and baking tests of the flour. In some cases the results of such efforts have been promising.

There exists, however, to the knowledge of the authors, no attempt hitherto at the improvement of wheat through the selection of pedigree strains or pure cultures, in which the tendency to produce the yellow berry has been followed satisfactorily through more than one generation of pure-bred plants; and this particular investigation, in the writers' opinion, is of fundamental importance in dealing with the problem.

It is certain that the yellow berry is an inferior type of kernel, and it is not unreasonable to suppose that strains comparatively free from a tendency to produce such grains might exist, just as, by analogy, strains or families have been found, of various economic plants, whose cell characters render them immune to the attacks of certain species of fungi which ordinarily beset the species.

Manifestly, the elimination of the yellow berry by such a method *is wholly dependent upon the extent to which the yellow berry is distinctively a heritable product,* and not a fluctuating variation common to all the strains of glutenous wheats when grown under certain seasonal conditions. That the appearance of the yellow berry in hard wheats is indeed a phenomenon in which the climatic conditions play an important part has long been recognized, and to the further and more particular knowledge of this fact part I of this bulletin is a contribution.

Nevertheless, that the appearance of the yellow berry is by no means due to climatic factors alone is proven by the following fact:

Among our mass-variety cultures, those wheats were examined *which were planted side by side on the same day, and which ripened on the same date. Among these, the percentages of yellow berry were found to vary widely.* A few illustrative examples to the point are given in the following table:

TABLE XVII.

No.	Year.	Date planted.	Date ripe.	Per cent. of yellow berry.
527	1905–'06	October 2...........	July 4................	1
510	1905–'06	October 2...........	July 4................	22
484	1905–'06	October 2...........	June 26.............	2
462	1905–'06	October 2...........	June 26.............	38
248	1906–'07	September 27........	July 2................	17
256	1906–'07	September 27........	July 2................	54
527	1906–'07	October 2...........	July 8................	16
506	1906–'07	October 2...........	July 8................	66

It may, moreover, be shown that most of the so-called "varieties," as they appear on the market, are really mixtures of wheats, which when separated are found to produce widely different amounts of yellow berry. For a few instances of these mixed varieties see table XVIII. What these examples so strikingly show is probably true, to a greater or less degree, of all commercial varieties of wheat.

By "segregation number" in the above table is meant that, from an original lot of seed bearing the name of a commercial "variety," distinct and different types of wheats—"segregates"—were selected out, and a serial number assigned to

TABLE XVIII.

Original number.	VARIETY NAME.	Segregation number.	Per cent. of yellow berry.
494		1338	47
		1339	17
543	Hungarian Red	1348	10
		1349	51
627	Japanese	1362	48
		1363	21
147	Pedigree Early Genesee Giant	1366	62
		1367	38

each. Here also it is clear that within a given so-called "variety," as it appears on the market, are found strains of different type which show distinct physiological differences so far as the production of yellow berry is concerned.

Since here, too, the different "segregates" chosen for illustration *were all planted on the same day, side by side, and matured their seed on the same date,* it is evident that the soil and climatic factors operative must have been exactly the same for all.

The question of the extent to which the tendency to produce the yellow berry may be an heritable one, independently of seasonal conditions, has been examined into for the wheat varieties under experiment, and for the two years 1905-'06 and 1906-'07.

For this purpose the varieties grown in 1906 were separated into four groups, according to the percentage amount of yellow berry produced by each. Group I contained those wheats in which from 1 to 25 per cent. of yellow berry was produced; group II, from 25 to 50 per cent.; group III, 51 to 75 per cent., and group IV, from 76 to 100 per cent. The average percentage of yellow berry produced by the wheat varieties of each group was determined. Table XIX gives a summary of these analyses, from which it will be observed that, with one very minor exception, the averages of the amount of yellow berry for each group take the same relative position in 1907 that they occupy in 1906.

It will be noted, by reference to the preceding table, that the wheats of 1907, with respect to the total average percentage amounts of yellow berry produced by each group as a whole, appear in every case, with one exception (column 4, group IV), when arranged in successive order, *to have been derived from groups having the same successive order in 1906.*

TABLE XIX.

Group No.	Number of varieties included.	1 Range of percentages of yellow berry within the groups, 1906.	2 Average percentage of yellow berry for each group, 1906.	3 Range of percentages of yellow berry within the groups, 1907.	4 Average percentage of yellow berry for each group, 1907.
I..............	61	1.25	12.78	0.83	36.95
II..............	38	26.50	38.34	0.89	38.68
III..............	26	51.75	61.65	17.72	45.84
IV..............	9	76.10	81.55	22.72	42.55

It is true that the group range of the offspring of 1907 (column 3) is wider than the original group range of those groups from which they sprang. It is highly probable that this is due, in part at least, to the mixed character of most of the commercial varieties under experiment. Were the varieties all pure-bred, it is unlikely, if the yellow berry tendency be inheritable at all, that the range of the offspring would be as wide as in the table.

However, allowing for the crude and imperfect materials, it at least appears as a fact that the location of the *minimum range of yellow berry in the varieties lies in those groups of 1907 that came from the minimum groups of 1906.* It will furthermore be noted that, when the averages are considered (column 4), while the minimum average is not so low in 1907 as in the corresponding parent groups for 1906, it is easy to see that the groups of 1907 fall into the same relative order as those of 1906 from which they sprang, in regard to percentage of the yellow berry. The minor exception, referred to previously, is the reversal of the order of the last two groups in column 4. The difference between them, however, of only 3.29 per cent., is negligible, as is also the difference between the first two groups, of 1.73 per cent.

What stands out very clearly, however, is the fact that from the ninety-nine varieties grown in 1906 which had 50 per cent. of yellow berry or under, with an average of 25.56 per cent., came offspring whose average percentage of yellow berry was 37.81 per cent. And, on the other hand, from thirty-five varieties in 1906 in which the yellow berry percentage lay between 50 and 100, with an average of 71.60 per cent., came offspring with an average percentage of yellow berry of only 44.19 per cent., although the group range was wider than that from which the selection came. The general conclusion from the data may be stated thus:

While on the one hand the vareties *low* in yellow berry (groups I and II) had progeny in 1907 which averaged 12.25 per cent. *higher* than the average of the corresponding parental groups for 1906, yet, on the other hand, the varieties *high* in yellow berry (groups III and IV) had progeny which averaged 27.41 per cent. *lower* than the average of the corresponding parental groups for 1906.

Without undertaking to use the materials at hand for constructing a regression table for the character in question, it will suffice to say that the data, as they stand, point strongly to a certain degree of actual inheritance of the yellow berry tendency, even as exhibited by such impure cultures as the commercial mass-varieties necessarily are.

It may be recalled that in table XVI there was a group of wheats which, in spite of their late ripening, produced high percentages of the yellow berry during both of the years covered by the experiment. This fact is opposed to the conclusions heretofore drawn that within a given season those wheats which ripen late, and which therefore carry their ripening period over into the warmer weather, produce less yellow berry.

As an explanation of this apparently contradictory evidence, it may be suggested that with the hereditary long growing period of those wheats, there may also coexist a strong hereditary tendency toward the production of the yellow berry, which physiological tendency persists despite the hotter weather of midsummer, resulting in a higher percentage of the yellow berry than is the case even with many of the earlier-ripening wheats.

That the length of the growing season in wheat varieties is itself a character that is strongly heritable may be seen from the following table, in which the wheats grown in 1906 are arranged in groups according to the length of their respective spring growing periods, with the offspring for 1907 arranged in groups corresponding to their respective parents, and with the averages determined as before. From this table, indicating the inheritance of length of vegetative period, and from table XIX, and tables XXII and XXIII (below), showing the inheritance of the tendency to produce yellow berry, there exists, in our judgment, a sufficient basis of evidence for the assumption that these two tendencies may occasionally occur together in the same individual.

TABLE XX. Length of spring vegetative period for parent varieties, 1906, and offspring, 1907.

No. of cases.........	29	6	58	28	7
Spring vegetative period, 1906 (days)..	106 to 110	111 to 115	116 to 120	121 to 125	126 to 130
Average for progeny, 1907 (days)..	124.2	124.5	124.8	129.7	128 0

In the preceding table, the varieties under experiment are grouped according to the duration of their respective spring vegetative periods. Beneath this grouping is given the average length of the spring vegetative period of the progeny of the several groups.

CULTURE TEST OF HARD WHEAT GRAINS AND YELLOW BERRIES.

From each of eight apparently pure varieties which contained a mixture of flinty and starchy kernels, 200 grains of each of these types were carefully selected. While of course there were present many intermediate types in the mass, only the extremely hard and the completely starchy grains were actually taken. Two thirty-foot rows including each of these types were planted side by side, on the same date in the fall of 1906, and were promptly harvested on the day when they were apparently ripe. The spikes were cut off, placed in loose sacks, and were immediately brought in and allowed to dry under cover. The grain was thrashed by hand, and the yield in gram weight of each row was carefully determined. All percentages of the yellow berry in the grain were then found, and by the same person.

In table XXI, following, appear the results of the study of the progeny of the hard and soft grains, and a close scrutiny of the table brings out the following facts:

1. The hard grains planted in 1906 were much heavier than the soft ones.
2. The yields from the heavy hard grains were greater than those from the lighter, softer kernels, with the exception of the case of No. 241, where the row of the soft wheat was on the outside of the plot, having therefore the advantage of additional growing space, and that of No. 501, which was a Poulard wheat.

The results as to yield are in accordance with those usually obtained from similar tests, and are probably due to the fact

TABLE XXI.

Serial number.	Character of grains planted.	Average air-dry weight of 100 grains.	Date ripe and harvested.	Characters of crop harvested.			
				Average weight of 100 grains.	Yield.	Specific gravity.	Per cent. of yellow berry.
		Grams.		*Grams.*	*Grams.*		
241	Soft*..	3.054	July 13	2.531	514	1.358	1 6
	Hard..	3.214	"	2.612	269	1 335	6.6
246	Soft...	3.008	"	2 601	344	1 334	14.0
	Hard..	3.114	"	2 546	360	1 336	8.7
249	Soft..	2.775	"	2.032	224	1 325	8 0
	Hard..	3.221	"	1.940	281	1.318	4.6
254	Soft...	3.008	"	2.335	250	1.333	2.7
	Hard..	3.353	"	2 434	329	1.340	2.5
466	Soft...	3.168	"	2.647	328	1.305	4.0
	Hard..	3 579	"	2 673	474	1 318	5.2
501	Soft†..	3 688	July 19	2 984	112	1.288	63.1
	Hard†.	3.989	"	2.403	71	1 270	72 5
534	Soft...	2.987	July 13	2 191	169	1.314	18.7
	Hard..	3.436	"	2 127	187	1.320	14 8
1303	Soft...	2 685	"	2.396	303	1 344	18.0
	Hard‡.	3.007	"	2 827	356	1.366	8 3
Total av'gs,	Soft...	3.046	July 13	2.458	280	1.325	16.71
	Hard..	3.363	"	2 392	291	1.325	15.40

* Disregard yield on account of outside row.
† Poulard wheat.
‡ Not an outside row.

Average yield: Soft, 270 grains; hard, 331 grains.
Average yellow berry: Soft, 10.1 per cent.; hard, 7.4 per cent.

that large, heavy seeds contain more reserve food material, enabling the plants to start more vigorously than those from lighter and smaller grains.

With the exception of Nos. 241 and 501, before referred to, and one other—No. 466—the offspring of the hard grains showed a slightly higher percentage of yellow berry than did the progeny of the soft grains.

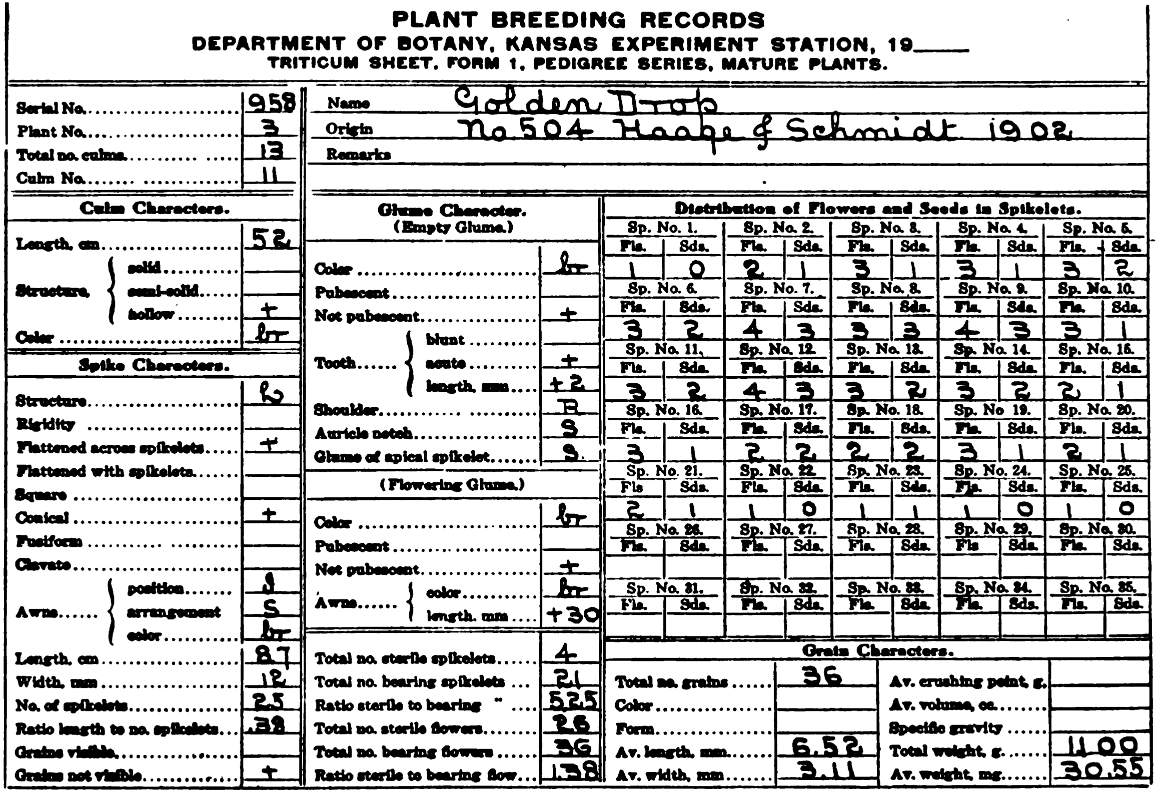
That the percentages of yellow berry obtained in the crop from hard seeds should average very little less than the percentages of yellow berry in the crop from the soft grains may be explained as follows:

Since yellow berry kernels may sometimes occur on the same spike with normal hard kernels, and since all the grains on the head have practically the same set of elementary characters, a selection of such yellow berry kernels for planting would not constitute a selection of a family of plants predisposed to the production of yellow berry at all. The offspring in such cases of the yellow berry and of the normal kernels would inherit like characters; and offspring of both sorts would possess the same ratio of hard to soft kernels.

As an explanation of the slight advantage of the hard grains in giving harvests which contained somewhat less of the yellow berry, the suggestion may be offered that the varieties used were not pure cultures of pedigree wheats, but were the usual mass-varieties of commerce, and consequently in all probability not homogeneous in point of descent. It may have been that these "varieties" were mixtures containing several sub-varieties, some of which, under identical conditions with others, would produce less of the yellow berry. It is plain that if such a mixture of the hard and soft grains were selected from at random, the selected hard grains would be apt to contain a slightly larger relative proportion of seeds from the harder sorts in the mixture, while the selected soft wheats or yellow berries would be apt to be, in large proportion, grains from those sorts in the mixture that naturally and normally produce a larger percentage of the yellow berry. The outcome would be that the progeny of the hard grains would verge slightly more *away* from the yellow berry tendency and the progeny of the soft or yellow berry grains would verge slightly more *towards* it. As a result of such selection, if long continued, a gradual and at last a considerable elimination of the sorts that tended toward the production of much yellow berry would follow. The improvement would be slow, because blindly achieved, and in all probability would never be permanent, on account of the almost practical impossibility of securing *total* elimination of the undesirable races in this way.

DEGREE OF INHERITANCE OF YELLOW BERRY IN PURE-BRED (PEDIGREE) WHEATS.

In the summer of 1906 a large number of spikes of wheat were selected from among the mass-varieties growing in the plots of the Department of Botany of this Experiment Station. These spikes or heads were chosen on account of certain apparently promising characters possessed by the plants which bore them, and they were intended to furnish the seed for other plants of pure "pedigreed" races of superior stocks. The reason that more than one head was not selected from any single plant was because of the fact that the plants grew close together in the row, and in the consequent tangle of roots and stems it is always impossible to ascertain with certainty where



PLANT BREEDING RECORDS
DEPARTMENT OF BOTANY, KANSAS EXPERIMENT STATION, 19____
TRITICUM SHEET. FORM 1. PEDIGREE SERIES. MATURE PLANTS.

Serial No.	958
Plant No.	3
Total no. culms	13
Culm No.	11

Name Golden Drop
Origin No 504 Haage & Schmidt 1902
Remarks

Culm Characters.		
Length, cm		52
Structure	solid	
	semi-solid	
	hollow	+
Color		br

Spike Characters.		
Structure		b
Rigidity		
Flattened across spikelets		+
Flattened with spikelets		
Square		
Conical		+
Fusiform		
Clavate		
Awns	position	d
	arrangement	S
	color	br
Length, cm		8.7
Width, mm		12
No. of spikelets		25
Ratio length to no. spikelets		.38
Grains visible		
Grains not visible		+

Glume Character. (Empty Glume.)		
Color		br
Pubescent		
Not pubescent		+
Tooth	blunt	
	acute	+
	length, mm	+2
Shoulder		R
Auricle notch		S
Glume of apical spikelet		S

(Flowering Glume.)		
Color		br
Pubescent		
Not pubescent		+
Awns	color	br
	length, mm	+30

Total no. sterile spikelets	4
Total no. bearing spikelets	21
Ratio sterile to bearing "	5.25
Total no. sterile flowers	26
Total no. bearing flowers	36
Ratio sterile to bearing flow.	1.38

Distribution of Flowers and Seeds in Spikelets.

Sp. No. 1.		Sp. No. 2.		Sp. No. 3.		Sp. No. 4.		Sp. No. 5.	
Fls.	Sds.	Fls.	Sds.	Fls.	Sds.	Fls.	Sds.	Fls.	Sds.
1	0	2	1	3	1	3	1	3	2
Sp. No. 6.		Sp. No. 7.		Sp. No. 8.		Sp. No. 9.		Sp. No. 10.	
Fls.	Sds.	Fls.	Sds.	Fls.	Sds.	Fls.	Sds.	Fls.	Sds.
3	2	4	3	3	3	4	3	3	1
Sp. No. 11.		Sp. No. 12.		Sp. No. 13.		Sp. No. 14.		Sp. No. 15.	
Fls.	Sds.	Fls.	Sds.	Fls.	Sds.	Fls.	Sds.	Fls.	Sds.
3	2	4	3	3	2	3	2	2	1
Sp. No. 16.		Sp. No. 17.		Sp. No. 18.		Sp. No 19.		Sp. No. 20.	
Fls.	Sds.	Fls.	Sds.	Fls.	Sds.	Fls.	Sds.	Fls.	Sds.
3	1	2	2	2	2	3	1	2	1
Sp. No. 21.		Sp. No. 22.		Sp. No. 23.		Sp. No. 24.		Sp. No. 25.	
Fls	Sds.	Fls.	Sds.	Fls.	Sds.	Fls.	Sds.	Fls.	Sds.
2	1	1	0	1	1	1	0	1	0
Sp. No. 26.		Sp. No. 27.		Sp. No. 28.		Sp. No. 29.		Sp. No. 30.	
Fls.	Sds.	Fls.	Sds.	Fls.	Sds.	Fls	Sds.	Fls.	Sds.
Sp. No. 31.		Sp. No. 32.		Sp. No. 33.		Sp. No. 34.		Sp. No. 35.	
Fls.	Sds.	Fls.	Sds.	Fls.	Sds.	Fls.	Sds.	Fls.	Sds.

Grain Characters.			
Total no. grains	36	Av. crushing point, g.	
Color		Av. volume, cc.	
Form		Specific gravity	
Av. length, mm.	6.52	Total weight, g.	1.100
Av. width, mm	3.11	Av. weight, mg.	30.55

PLATE 1. Wheat-breeding record-sheet, showing the manner in which the data are recorded.

one plant ends and another begins. One is therefore compelled to commence with single heads unless the individuals are growing in nursery plots.

All of the visible morphological characters of these heads, of their grains, and of the culms which bore them, were carefully entered on a special set of blanks which are now on file in the records of this department. Plate I is an illustration of such a record sheet, in which some fifty characters are accounted for.

An examination of the grain from each of the heads was made with especial reference to the presence or absence of the yellow berry, and, while it is very true that a single spike is not a perfect index to the character of all of the other spikes on the plant, and while the character of the grains may vary somewhat even within the same plant, yet when enough cases are considered, the writers believe, as the following table will indicate, that at least extremely suggestive data appear with reference to inheritance of the tendency to produce the yellow berry. For this reason, a comparative study was made of the percentage amounts of yellow berry produced in the original heads selected, and in their progeny harvested in 1907. For convenience, the original selections are here thrown into groups, according to the percentage amounts of yellow berry produced in each spike.

TABLE XXII. Inheritance of yellow berry in pure races of (pedigree) wheat.

	Group number—				
	I.	II.	III.	IV.	V.
Number of cases	35	38	17	9	6
Percentage range of yellow berry in parentage, 1906	0	1-25	26-50	51-75	76-100
Percentage range of yellow berry in progeny of the foregoing groups, 1907	0-20	0-30	0-68	1-38	0-49
Mean percentage of yellow berry in 1907	3.9	7.9	17.1	14.9	23.5

An inspection of the above table leads to some interesting inferences. It will be noted that while the progeny of each of the 1906 groups have a lower range limit of zero, yet when the higher range limit is considered the effect of selection becomes manifest in the fact that the progeny in the high-range groups of 1906 are also high in 1907, in respect to maximum amount of yellow berry; while the progeny of the low-range groups of

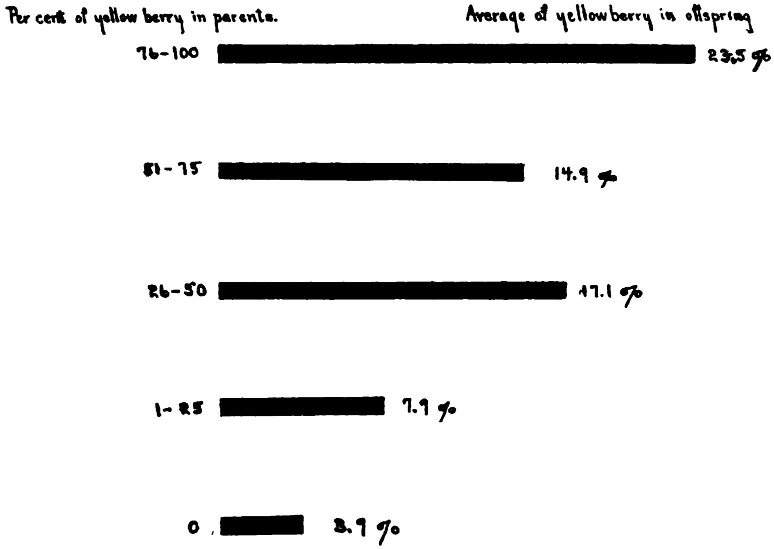


PLATE 2. Showing graphically the degree of inheritance of the tendency to produce yellow berry in pedigree races of wheat.

1906 are low in 1907. That groups III and IV, in 1907, are not in the same relative order with respect to the maximum as their parentage of 1906 may be ascribable in part to the small number of cases involved, with a consequent undue influence of occasional erratic variants.

Reference to the mean per cents. in the last column brings even these irregular numbers almost completely into the relative order of the parentage of 1906. As a matter of fact, the high average and the excessively high range of group III (1907) was caused by the presence of one case, which produced 68 per cent. of yellow berry, and which markedly modified the mean. Were this case excluded, the group would fall into its correct position.

Although it is a fact that many of those parental spikes in which no yellow berries were found produced yellow berries in their 1907 offspring, and while those parents, which, as in group IV, contained a high percentage of yellow berry, produced much smaller amounts in the offspring, yet the regression toward a common race mean is not so marked in the case of the pedigree wheat cultures (table XXII) as when mass-varieties are used.

This fact is strikingly shown in table XXIII:

TABLE XXIII. Distribution of parents and offspring with respect to the production of the yellow berry, as exhibited by mass-variety cultures, pedigree cultures, and selected hard and soft grains from mass-varieties.

Number and distribution of cases.							Per cent of yellow berry—			
							In parents.	Average in offspring.		
1	2	3	4	5	6	7	8	9	10	11
Group No..........	Number of mass-variety cultures..	Per cent. of all cases..........	Number of pedigree cultures....	Per cent. of all cases..........	Selections of hard and soft from mass-varieties...	Per cent. of all cases..........	Percentage range of yellow berry in parents, 1906..	Mass-variety cultures........	Pedigree cultures.	Selected hard and soft grains from mass-varieties...
I	0	0	35	33	8	50	0	0	3.9	15.40
II	61	46	38	36	0	0	1–25	36.95	7.9	
III	38	28	17	18	0	0	26–50	38.68	17.1	
IV	26	19	9	9	0	0	51–75	45.84	14.9	
V	9	7	6	6	8	50	76–100	42.55	23.5	15.7

From the table it is seen that the difference between the averages for the highest and the lowest groups in the mass-varieties was only about 8 per cent.; in the selections of hard and soft grains from certain mass-varieties it was but 0.3 per cent.; while in the pedigree heads the difference between the highest and lowest averages was 20 per cent. Moreover, in the first progeny group of the pedigree wheats for 1907, *a little over one-third of the cases produced no yellow berry at all* (a fact which the general table does not show), *while the average of all the cases was but 3.9 per cent.* On the other hand, by the other method of selection, *there were no cases whatever where the offspring were free from yellow berry;* and the averages for the lowest groups in the case of the mass-varieties, and of the selected hard and soft grains, were 36.95 per cent. and 15.40 per cent., respectively.

This conclusively demonstrates the superiority of the pedigree method as compared with other methods of selection, due to the evident fact that the pedigree cultures represent isolated stable races, instead of the congeries of mixtures of strains which form the commercial varieties.

Table XXIII, however, calls for some further explanation. Taking the mass-variety cultures (common commercial varieties) for 1906, the cultures of hard and soft (yellow berry) grains separated out from a number of such varieties, and the pure (pedigree) cultures of our wheats for 1906, including 134, 16 and 105 cases in each category, respectively, a careful determination was made of the percentage amount of yellow berry in each. The wheats of each category were then thrown into five groups, according to the amounts of yellow berry found.

Owing to the small number of grains available in many cases in the parental groups of the pedigree cultures, it was decided not to attempt to calculate the mean for yellow berry percentage *within* each group, but simply to present the total range of the groups. That the distribution within each group was sufficiently normal was ascertained by inspection. It is further indicated by the fact that, if the distribution of the number of cases be taken in their order from groups I to V, no irregularities will appear.

Now the fact that the original pedigree heads fall into the mode of distribution that they do with respect to the yellow berry is, of course, necessarily a matter of chance. That the *offspring*, however, of the pedigree lots, follows the distribution of the parents to such a high degree in respect to the percentage composition of yellow berry is remarkable. That the mass-variety and selected hard and soft lots follow the same law, although less rigidly, is what would be expected of such lots if the yellow berry tendency is heritable at all in the constituent units which taken together form the group called a "variety."

On examination of table XXIII, columns 8, 9 and 10, it is seen that the *mean percentages* of yellow berry in the mass-variety and pedigree cultures fall almost exactly into the same relative order as the groups of percentage ranges of the parents (column 8). While it is to be inferred that there is regression here, the data were not thought suitable for presentation in the form of a regression table, especially since the means within the two groups of parents could not be calculated to advantage. Therefore, while it is, strictly speaking, incorrect to compare the mean percentage of the progeny with the group range of the parents for a given character, yet, given a uniform and normal distribution *within* the parental groups, such a comparison has practical value, in the absence of the possibility for the more exact analysis of a regression table. It appears, in plain words, in columns 8, 9, 10, table XXII, *that with the percentage increase of yellow berry in the parents follows a mean percentage increase of yellow berry in the offspring.* What is decidedly of supreme importance, so far as this investigation is concerned, is the *very evident fact of the superiority of the pedigree-culture method so far as the elimination of the yellow berry is concerned.* For example, while there were no cases of mass-variety lots of parents containing no yellow berry, there were sixty-one cases (46 per cent. of the total) in which the percentage of yellow berry ranged from 1 to 25 per cent. From these came progeny in 1907 in which the *mean percentage of the yellow berry was nearly 37.* On the other hand, among the pedigree cultures, there were thirty-eight in all, or 36 per cent. of the total examined, which fell into the 1 to 25 per cent. class of the parents, but which in 1907 had a *mean percentage of yellow berry of only 7.9.*

Still more striking is the fact that the *minimum or zero class of the parents gave rise also to the minimum class of the offspring (3.9 per cent.) in the case of the pedigree wheats.*

In view of the fact that but one head from each plant of the pedigree parent stocks had to furnish the grains on which an estimate of the percentage yield of yellow berry in the plant as a whole was based, the result is really surprisingly confirmatory of our hypothesis that the yellow berry is a "tendency," which finds expression in certain strains or races more markedly than in others, *and is heritable.*

In so far as this is the case, the yellow berry problem is one which is capable of being handled by the breeder with a view to the propagation of pure strains of wheat which may be found free from the yellow berry under all conditions. It therefore seems reasonable to hope that from a group of pure strains of pedigree wheats producing no yellow berry for two successive years—which we have—a race of wheat may be derived which will go entirely wide of this tendency to deterioration in the product. If the next few years' work confirms the results of the past two, the outcome, so far as the Kansas hard wheat interest is concerned, will be a distinctively valuable one.

The results thus far, at all events, brilliantly demonstrate the fact that the pedigree system of cereal breeding is the only one whereby definite and permanent results may be effected in breeding improved races of the grains, since by the pedigree method alone can the improved strains be isolated and separated from those of inferior character.

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The Bulletins of the Experiment Station are sent free to applicants. Farmers are invited to send the names of others who would value them and samples will be sent, with return cards upon which applications for future issues may be made.

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No. 157. **Nov. '08.**

Experiment Station.

Kansas State Agricultural College.

Bulletin No. 157—November, 1908.

Bacteriology Department.

Studies on Hog Cholera and Preventive Treatment.

MANHATTAN, KANSAS.
1908.

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Experiment Station
of the
Kansas State Agricultural College,
Manhattan.

Bulletin No. 157—November, 1908.
Bacteriology Department.
WALTER E. KING, M. S., Bacteriologist.

Studies on Hog Cholera and Preventive Treatment.

ACKNOWLEDGMENT.

Dr. Chas. T. McClintock, director of the biological laboratory of Parke, Davis & Co., Detroit, Mich., has conducted a continuous line of investigation on hog cholera for the last twelve years. After a series of studies on the *Bacillus cholera suis*, including a study of the value of agglutination for the diagnosis of the disease, he began an aggressive line of work with the filterable virus. He made many attempts to attenuate virulent hog-cholera blood, using the various physical and chemical agents, particularly those suggested by his own work and that of others on smallpox vaccine. All of these attempts were unsuccessful. At that time it occurred to Doctor McClintock that Jenner's work might apply to vaccination against hog cholera; that even though we had no other animal susceptible to the disease, a residence in the body of another animal might attenuate the hog-cholera virus without totally destroying it.

The opportunity to carry on the work outlined in the following pages is largely, if not wholly, due to Doctor McClintock. Furthermore, the method of producing the experimental vaccine, such as has been used in the following experiments, was first suggested by Doctor McClintock.

NOTE.—The plates referred to in this Bulletin are photo reproductions and may be found grouped at the end of the article.

The studies on the value of this vaccine and methods of producing the same have been carried out jointly. The earlier experiments were made in the research department of Parke, Davis & Co., Detroit, Mich., and the later ones at the Kansas State Experiment Station.

I.

INTRODUCTION.

The suppression of the disease, hog cholera, a problem which is recognized as one of great importance to the agricultural interests of the United States, has received considerable attention during the last twenty years. At the present time few problems are as intimately associated with the agricultural economy of the state of Kansas as that which is related to the practical eradication of this animal disease.

Reports from various parts of the state give conclusive evidence of the great prevalence of hog cholera at this time. Hundreds of Kansas farms have become infected and thousands of hogs have perished during the past few months from this disease. The increased prevalence of hog cholera during the past season may possibly be attributed to the excessive rains during the late spring and early summer months. Under such conditions, relative to rainfall, the hog-cholera virus may be washed from infected pens and yards into creeks and small streams, these tributaries emptying into rivers and flooded districts, thus sweeping the infection over large areas. In addition to the simple mechanical action involved in this manner of spreading the disease, the heavy rains during the past season served to keep up a high moisture content of the soil. The presence of plenty of moisture is, of course, favorable to the growth and multiplication of the lower organisms. Such a favorable condition, therefore, may have had considerable influence in spreading the disease and in maintaining the high degree of virulence of the material. Other means of dissemination, such as dogs, birds and boots of stock buyers, have doubtless contributed their share toward the wide distribution of the disease.

In 1885 Dr. Theobald Smith and Dr. D. E. Salmon isolated *Bacillus cholera suis* and described that organism as the specific cause of hog cholera. Since that time a continuous line of investigation has been conducted by the Bureau of Animal Industry, United States Department of Agriculture, for the purpose of discovering some protective inoculation or treatment against the disease. During the past few years several investigators, both in Europe and America, have been actively engaged in this study. In 1903 the Bureau of Animal Industry published a preliminary report[1] in which it was stated that it was possible to transmit hog cholera to healthy swine by injecting the filtered serum of hogs suffering from cholera. Bacteriological examination proved the absence in this filtered material of *B. cholera suis* or other bacteria capable of growing on ordinary culture media. Since the appearance of the above report the investigations of the Bureau of Animal Industry, as well as the results of extensive work in other laboratories, have confirmed the belief that *Bacillus cholera suis* is not the specific cause of hog cholera, or, more cautiously stated, that *Bacillus cholera suis* is not the etiological factor in all forms of hog cholera.

It seems possible that *Bacillus cholera suis* may be a variety of the common intestinal parasite, *Bacillus coli communis*. The hog-cholera organism is pathogenic when injected in culture into experimental animals, including the hog; nevertheless, such is also true of *Bacillus coli communis*. Again, it may be possible that in those instances in which *Bacillus cholera suis* can be isolated from the liver, spleen and other tissues of hogs dead from cholera that the organism has appeared in those tissues, having migrated from the intestinal mucosa, as does the colon organism when it frequently appears in the spleen, liver, and tissues other than the intestinal mucosa, during certain processes of the disease. In other words, the presence of *B. cholera suis* in certain cases may indicate the result and not the cause of the disease.

Bacillus cholera suis is certainly not exclusively associated with the tissues of the diseased or of healthy hogs. White[2] isolated an organism culturally identical with the hog-cholera bacillus from the intestine of healthy honey-bees.

McClintock, Boxmeyer and Siffer[3] made a careful study of hog-cholera blood, relative to the presence of agglutinins for *Bacillus cholera suis*. In their work twenty-two specimens of normal hog blood and fifty-seven specimens of blood from cases of hog cholera were examined. They summarize the results obtained by the statement that "Agglutination is of no value for the diagnosis of hog cholera as the disease is at present defined." Hottinger,[4] in a recent article on "*Bacillus suipestifer,*" in which he bases his observations upon certain comparative cultural and pathogenic characters of *B. cholera suis* and *B. coli communis,* concludes as follows: "From the foregoing observations, it would appear that *B. cholera suis* is a migratory colon-like intestinal organism, having acquired pathogenic properties, which is always, however not exclusively, found in cases of hog cholera." According to the present state of knowledge regarding the etiological factor involved in hog cholera, many investigators are led to believe that certain assumptions may be correct. Experimental evidence certainly indicates the presence of some living organism in hog-cholera virus.

---

[1] De Schweinitz and Dorset: Bureau of Animal Industry, 1903, circular 41.

[2] White, G. F.: Bureau of Entomology, Technical Series No. 14, 1906.

[3] McClintock, Boxmeyer and Siffer: Journal of Infectious Diseases, vol. II, No. 2, March 1, 1905.

II.

ATTEMPTED CULTIVATION OF FILTERED VIRUS OF HOG CHOLERA.

Collodium Sac Method.

The brilliant investigations of Nocard and Roux,[5] in employing the collodium sac as a means of artificially growing the virus of contagious pleuropneumonia in cattle, resulted in the identification of a very small, almost ultra-microscopic, motile organism. By inoculating cultures of these minute organisms, Nocard and Roux produced the disease in healthy cattle. The results of Nocard's work suggested the possible advantages of such a procedure with reference to the filterable hog-cholera virus. A series of experiments therefore were conducted in using the collodium-sac method as a possible means of artificially cultivating the virus of hog cholera. This work was begun in August, 1905, by Dr. C. H. Boxmeyer, and after September 1, 1905, was conducted by the writer.

Collodium sacs, prepared according to Novy,[6] were filled with hog-serum broth as the artificial culture medium. This medium was prepared by the addition of equal parts of normal hog serum and ordinary nutrient broth. These media were inoculated with the hog-cholera virus or serum, and after inoculation were placed in the abdominal cavity of the rabbit, where they were allowed to remain for several days. At the time of each serial passage, check collodium sacs, containing the uninoculated media, were placed in the abdominal cavity of the rabbit. The first passage through the rabbit consisted of collodium sacs filled with equal parts of normal hog-serum broth and virulent hog-cholera serum from hog No. 147. This strain of virus originated from an outbreak at Pontiac, Mich. The serum from hog No. 147, before the inoculation of the collodium sac, was filtered through a Chamberland porcelain filter. The collodium sacs of the first passage were allowed to remain in the abdominal cavity of the rabbit for a period of twenty days. At the expiration of that time the four rabbits

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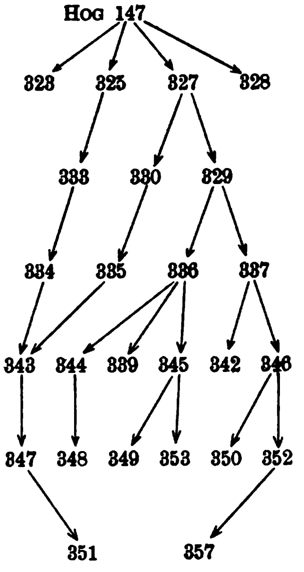
[4] Hottinger, Robert: Centralblatt für Bakteriologie, etc. Orig. Bd. XLVII, July, 1908, p. 186.

[5] Nocard: Handbuch d. Path. Micro-organismen, 1903, III, p. 682. Nocard and Roux: "Le Microbe de la peripneumonie." Recueil de med. Veterinaire, March 24, 1898, p. 218.

[6] Novy, F. G.: Laboratory Work in Bacteriology, second ed., p. 499.

TABLE 1.

COLLODIUM SAC PASSAGES.



Number generation.	Period of time allowed for each passage.	Number of rabbits used and diagram showing source of inoculations of each collodium sac.	Inoculations. Parts contents preceding sac to parts of normal hog-serum broth.	Dilution of original virus from Hog 147
		Hog 147		
1st	20 days	Rabbits 323 325 327 328	1 to 1	$\frac{1}{2}$
2nd	6 days	Rabbits 333 330 329	1 to 9	$\frac{1}{20}$
3rd	25 days	Rabbits 334 335 336 337	1 to 30	$\frac{1}{600}$
4th	16 days	Rabbits 343 344 339 345 342 346	1 to 50	$\frac{1}{3000}$
5th	10 days	Rabbits 347 348 349 353 350 352	1 to 30	$\frac{1}{90000}$
6th	10 days	Rabbits 351 357	1 to 20	$\frac{1}{800000}$

which contained the inoculated and uninoculated (control) collodium sacs were anesthetized and the sacs removed.

After a careful bacteriological examination of the contents of the collodium sacs, transfers were made from the contents of the inoculated sacs of the first passage into a second series of normal hog-serum media, and the second series was subjected to a second passage through the rabbit. After this manner the original filtered virus from hog No. 147 was passed through six generations or passages in the abdominal cavity of the rabbit. Table 1 shows in condensed form the time duration for each passage, extent of dilution of the original hog-cholera virus, and the number of the rabbit used in each passage.

A very careful bacteriological examination was made of the contents of each collodium sac after its removal from the abdominal cavity of the rabbit. Several of the sacs (in rabbits 323, 328, 339, 348, 349, 350 and 353) were found to be contaminated and were not used for reinoculation. Contents of collodium capsules 334, 335 and 343, which were contaminated with micrococci, were filtered through a Pasteur filter, and from their filtrates, after bacteriological examination, sacs 343, 344, 339, 345 and 347 of succeeding generations were respectively inoculated.

In no instance could the presence of any growth be detected in the contents of the collodium capsules. The contents of each sac was subjected to the most careful microscopical examination. Various attempts were made to obtain growths by making transfers from the collodium-sac contents to coagulated normal hog-serum media, normal hog-serum bouillon and normal rabbit-serum bouillon. Experimental animals were inoculated with material from the capsules.

Frequently a slight cloudiness could be detected, which, upon comparison with the control sacs, was found not to denote the presence of any apparent growth. This cloudiness appeared to be caused by a precipitate which probably resulted from the hog serum. At the completion of the sixth passage a hog was injected with some of the contents of sacs from rabbits 351 and 357, with no apparent results.

III.

IMMUNIZATION AGAINST THE DISEASE.

The study of hog cholera in all its various phases centers in one intensely practical problem, namely, that of preventive inoculation. Before the recognition of the fact that *Bacillus cholera suis* was not the specific cause of the "filterable-virus form" of the disease, many ineffectual attempts were made to produce some protective substance, using the hog-cholera organism as the basis. Since the time that *Bacillus cholera suis* has been practically eliminated as the etiological factor of the disease, various attempts have been made to cultivate artificially the filterable virus. All of these attempts have produced negative results. The attention of many investigators therefore has been turned toward the production of a vaccine or antitoxin for the disease, using the filterable virus as a basis.

Attempts to attenuate the hog-cholera virus by the use of various chemicals and by drying at different temperatures have thus far met with failure.

In 1897 Kolle and Turner[7] published the results which attended their method of simultaneous vaccination in combating rinderpest in South Africa. The simultaneous method of vaccination of healthy hogs as a protection against hog cholera has been the subject of an extensive line of experimental work by the Bureau of Animal Industry, United States Department of Agriculture. As a result of their work the Bureau of Animal Industry has recently developed the method to such an extent that several state experiment stations are making preparations to manufacture the vaccine and supply the product at cost to swine owners. The essential features of this method consist in the subcutaneous, simultaneous injection of hyper-immune serum and disease-producing blood into the healthy hog. In other words, the healthy animal is inoculated with from 1 to 3 cc. of hog-cholera virus and at the same time receives from 10 to 30 cc. of serum from a hog which has been hyper-immunized against the disease. Apparently the reaction which follows the inoculation with the virus is inhibited by the influence of the hyper-immune serum and the vaccinated animal consequently acquires a sufficient degree of immunity to protect it against subsequent exposures to hog cholera. The duration of immunity extends over a period of several months. The hyper-immune serum is obtained from hogs which are first immunized either through natural or acquired immunity, and later are subjected to hypodermic injections of large quantities of hog-cholera blood serum.

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[7] Kolle and Turner: Deutsch Med. Wochnsch, 1897, p. 793.

There is no question as to the efficiency of the simultaneous method. Extensive successful experimentation by the Bureau of Animal Industry, as well as confirmatory experimental evidence obtained by other workers, shows beyond a doubt that the above procedure successfully vaccinates. The United States Department of Agriculture is to be commended for its persistent and effective work upon hog cholera. Much credit is due to those connected with the Bureau of Animal Industry for their determined and intelligent scientific efforts to eradicate this disease. From a practical point of view, however, "Dorset's Hog Cholera Vaccine," or the simultaneous method of vaccination, has certain important disadvantages. "Dorset's Hog Cholera Vaccine" is not, at present, practical, because of the expense involved in its preparation. The fundamental reason for this expense is the fact that a hog yields only a small amount of blood in comparison with most other animals. At the beginning of the preparatory procedure, hogs are immunized, either naturally or artificially, against the disease. It is presumable that during this process some animals may be lost. With the next step the immune hogs are hyper-immunized by the injection of relatively large quantities of hog-cholera serum. This serum must be procured from a large number of hogs suffering from the acute form of the disease. These animals may be located at the vaccine plant itself, or in the field on various infected farms. The third and last essential step is the obtainment of the blood serum from the hyper-immunized animals. This is the most disappointing part of the whole procedure. Whether the hyper-immune animal is relieved at one time of all its blood from the carotid artery or whether it is required to yield its body fluid by several instalments from the tail, the results are not highly encouraging, because of the relatively small amount of blood which can be secured. This fact, taken in connection with the experimental evidence that ten or more cubic centimeters of the immune serum are necessary in the preventive treatment of a fifty-pound pig, presents serious difficulties to those who may wish to apply the method in a practical way.

Again, the simultaneous method of vaccination may not be of advantage because of the danger accompanying the use of the necessary pathogenic hog-cholera virus as a part of the vaccination. There is always more or less risk involved in distributing various vaccines. It seems reasonable to suppose that, in comparison with attenuated products such as black-leg vaccine, there would be much more risk concerned in placing upon the market a hog-cholera vaccine, one part of which is virulent hog-cholera serum. The danger that might follow the broadcast distribution of hog-cholera virus, in some instances among careless veterinarians and uninformed farmers, cannot be ignored.

IV.

ATTEMPTED ATTENUATION OF HOG-CHOLERA VIRUS BY PASSAGE THROUGH ANIMALS OTHER THAN THE HOG.

Various unsuccessful attempts have been made to communicate the disease of hog cholera to animals other than the hog. Repeated inoculations have shown that the common laboratory animals are not susceptible to the filterable virus.

In 1905 a number of series of experiments were undertaken by the writer in an attempt to determine whether hog-cholera serum could be attenuated or modified by passage through some domesticated animal. The sheep was the first animal upon which any extensive work was conducted. About fifteen sheep were used. Most of the animals were injected in the jugular vein with hog-cholera serum, the average amount injected being about 100 cc. The sheep were bled at varying intervals of time and their serums introduced into healthy hogs. Several days after treatment with the sheep serum, the hogs, together with controls, were exposed to hog cholera. This work was attended with variable results, some negative, some positive, all, on the whole, distinctly lacking in uniformity. The general conclusion was reached that under some conditions passage through the sheep attenuated the virus in such a way that it would successfully vaccinate healthy hogs. It appeared, however, that no definite degree of uniformity or standardization of the experimental sheep-serum vaccine could be obtained. The employment of the sheep was therefore suspended, and the next animal used was the donkey.

The results obtained in the experimental work with the donkey-serum vaccine were more encouraging. On the whole, these experiments were quite uniform. One of these series appears in the following pages. After some work with the donkey, the horse was used as a medium in attempting to produce a satisfactory vaccine. The horse was substituted for the donkey because of the general adaptability of the horse to such work and the comparatively large yield of blood which may be obtained from this animal. Uhlenhuth, Hubener, Xylander and Bohtz,[8] in 1908, stated that "the serum of the horse and donkey which were treated with repeated intravenous injections of virus containing fluids had neither a protective nor a healing property. Whether the hyper-immunization of the animal will enhance the production of anti-bodies must be determined."

No attempt has been made in this work to produce an experimental hog-cholera antitoxin from the horse. The work has been directed more particularly toward the attempted production of a horse-serum hog-cholera vaccine.

V.

POSSIBLE TOXIC ACTION OF HOG-CHOLERA SERUM ON THE HEALTHY HORSE.

Repeated observations at the Kansas Experiment Station have shown that the intravenous injection of hog-cholera serum into the horse produces in that animal immediate and well-marked symptoms. The most pronounced symptoms are accelerated pulse, followed by irregular and weakened heart action, quickened respiratory functions, and violent peristalsis. The writer has found that the average horse cannot receive at one time more than 150 to 200 cc. of virulent hog-cholera serum. Experiments indicate that an intravenous dose in excess of from 150 to 200 cc. will invariably cause very serious disturbances and frequently death. The symptoms appear soon after the injection of the virus and continue from one to six hours. Not until comparatively recently in the course of this investigation has much attention been paid to the possible toxic action of hog-cholera virus upon the horse. The serious disturbances caused by such injections were carefully noted, but the impression was held that the symptoms were produced simply by the direct introduction of foreign serum into the circulatory system of the animal. The following appended notes show some of the observations which have been made and which suggest the toxicity of hog-cholera serum for the horse when injected intravenously:

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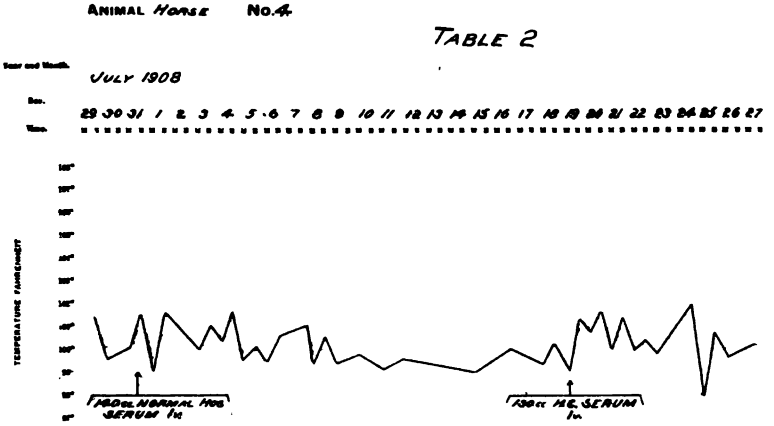
[8] Uhlenhuth, Hubener, Xylander, Bohtz: "Untersuchungen über das Wesen und die Bekampfung der Schweinepest," Arb. A. d. Kaiserl. Gesundheitsamt, Bd. 27, 1908, H. 3.

Horse No. 4, bay gelding, weight about 1300 pounds, in good condition, except lameness in right front limb due to contracted tendon. July 31, 1908, four P. M., horse No. 4 was injected in jugular vein with 140 cc. normal hog serum. Fifteen minutes after injection heart action and respiration slightly accelerated. One hour after injection temperature was 103 degrees. One-half hour after treatment a few raised blotches or pimples appeared on the skin. August 1, eight A. M., temperature normal and skin eruptions had disappeared.

August 19, 9:25 A. M., same horse (No. 4) injected with 130 cc. of Norwood, Kan., strain, filtered hog-cholera serum. Immediately after treatment the respiration and heart action were greatly accelerated, both rapidly increased for twenty minutes. One-half hour after injection heart became depressed and pulse almost obliterated. At this time the animal broke out in a profuse, cold, clammy sweat. At the end of forty-five minutes the horse became very weak, staggered and fell. Eye dull and listless. During this time peristalsis was very violent, within twenty minutes after treatment the animal having had ten profuse watery evacuations. The effect in this particular was like that from a dose of eserin. One-half hour after injection the animal received orally four ounces of alcohol, and forty-five minutes afterwards one-fourth grain of digitalin was injected subcutaneously. After two hours the animal began to slowly recover, and by evening appeared normal with the exception of a condition of extreme exhaustion. The temperature of horse No. 4 during the above treatment appears in the accompanying chart (table 2):



The results of the above experiment were far from conclusive, in the first place, because of the possibility of some reaction allied to anaphylaxis. Rosenau and Anderson[9] have called attention to such a condition of sensitization which is produced by the introduction of repeated injections of horse serum into the guinea-pig. It perhaps might be suspected, therefore, that horse No. 4, which had received an intravenous injection of normal hog serum twenty days before the intravenous injection of hog serum, had become sensitized to the hog serum to such an extent that the marked symptoms following the second injection were those pertaining to some reaction resembling anaphylaxis.

In order that this point relative to a possible anaphylactic reaction might be made more clear, a second horse was injected in the jugular vein, at intervals on the average of every seven days, with increasingly larger doses of hog-cholera serum. The animal received seven treatments after this manner. The horse received the seventh intravenous injection of hog-cholera serum, consisting of 75 cc., on August 11, 1908. Eleven days afterward the animal was injected with normal hog serum. The following observations and appended temperature chart give the data on this experiment:

Horse No. 2, gray gelding, in fair condition. This animal had received the following injections, intravenously, of hog-cholera serum (Norwood strain): July 4, 3 cc.; July 7, 6 cc.; July 17, 17 cc.; July 21, 30 cc.; July 28, 42 cc.; August 3, 68 cc.

On August 11, 1908, 10 A. M., horse No. 2 was injected with 75 cc. of hog-cholera serum (Norwood, Kan., strain). Five minutes after treatment the animal broke out in a copious, cold, clammy perspiration. The respiration was painfully accelerated and heart action rapid, at times very irregular. The heart finally became weak and the pulse was almost obliterated. Peristalsis very active and severe purging and watery evacuations followed. These symptoms extended in grave form over a period of about three hours. No stimulants were administered, and after three and one-half hours the animal gradually became more comfortable. Six hours after the injection the respiratory functions were nearly normal although the heart was still weak and the animal was greatly exhausted. Seven hours after the treatment the temperature was nearly 104 degrees. (See table 3, page 49.)

On August 22 the same animal, horse No. 2, received intravenously 85 cc. of normal hog serum. After treatment the animal showed slightly accelerated pulse and respiration. These disturbances were detected by careful examination. Five minutes after injection the horse was turned out in paddock and immediately started eating grass. The animal was carefully watched for some time. However, no symptoms other than very slight disturbances of the heart and respiration were noted.

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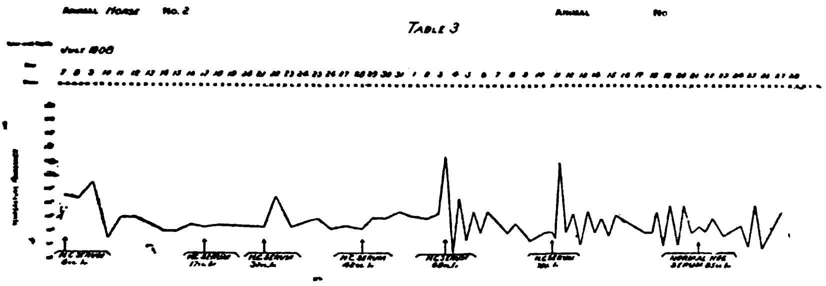
[9] Resenau and Anderson: "A Study of the Cause of Sudden Death Following the Injection of Horse Serum" and "Further Studies upon Anaphylaxis," Bulletins 29 and 45, Hyg. Lab. U. S. Pub. Health and Mar. Hosp. Serv., Wash.



It will be noticed in both experiments indicated above that in each instance the animal received of the normal hog serum 10 cc. in excess of the amount of hog-cholera serum injected. In both instances the hog-cholera virus, in comparison with the normal hog serum, produced marked symptoms which strongly suggest the toxicity of the cholera virus upon the horse.

VI.

MODIFIED CONDITION OF VIRULENT HOG-CHOLERA SERUM AFTER SHORTER OR LONGER RESIDENCE IN THE BLOOD OF THE DONKEY AND HORSE.

In the experimental use of the horse as a medium for the modification of the hog-cholera virus the work logically resolves itself into the solution of certain definite points. Fundamentally, the subsequent experiments depend upon the proof of the fact that a residence in the blood of the horse causes attenuative changes to take place in the hog-cholera virus. If the virus does become attenuated, experiments must show whether the modifications of the virus are reasonably uniform and under what conditions the attenuation takes place. More specifically, a determination must be made of the exact period of residence in the blood of the horse which will cause the proper degree of attenuation, so that the recovered modified hog-cholera virus will act as a vaccine and not as a disease-producing agent.

In carrying out these experiments the horse is injected in the jugular vein with a given quantity of virulent hog-cholera serum. The amount of virus introduced intravenously, depending upon the animal used, varies from 85 to 200 cc.

The horse is then bled at various intervals of time after the injection. The blood is placed in a refrigerator, and after a few days the equine serum is collected and tested upon healthy swine.

1. *Strain of filterable hog-cholera virus used in present investigation.*

The strain of hog-cholera virus which is now employed in the present investigation was obtained from an outbreak at Norwood, Kan. This material represents a very acute type of the disease and is well adapted to use in experimental work. The history of this outbreak is as follows:

On July 14, 1908, the farm of Clinton Eversol, one-half mile west of station of Norwood, was visited. It was found that acute hog cholera existed on this farm. Three weeks before the time of visit, Mr. Eversol had a herd of 200 hogs. On July 14, he probably had left about one-third of the original herd of 200. The disease affected the young pigs in a more acute manner than the older hogs. There were probably 40 or 50 spring pigs, all of which showed symptoms of the disease in various stages. Some of the sows were sick and several of them had died. A pig weighing perhaps seventy-five or eighty pounds, which had showed typical symptoms of hog cholera for a few days, was bled aseptically from the cartoid artery. After bleeding a careful *post-mortem* was made, and typical lesions of severe hog cholera were found. The skin of the ventral portion of the body was discolored; the ears were purplish; subcutaneous tissues contained blood extravasation; portions of the dependent lobes of the lungs were hepatized; heart apparently normal; liver normal; kidneys showed a few petechiæ. The spleen was very much enlarged and gorged with blood. The cæcum and large intestine showed the presence of very typical ulcers. The spleen and specimens of the intestinal ulcers were brought to the laboratory and preserved as museum specimens.

Origin of the Outbreak.—According to the statements of Mr. Eversol, an epizootic of hog cholera existed last fall and winter in that county and north of it. During the very rainy season last spring and early summer his hogs had access to the overflow of water from a creek which runs through the farm.

It is believed that the virus was conveyed by the creek, coming down from the infected farms north of it. As evidence of this origin of the outbreak, it was found that four other farms in the immediate locality were infected with hog cholera, and that the hogs belonging on these farms had had access to the creek water. Several farms in the neighborhood bordering on this creek were free from cholera, but the hogs on these did not have access to the creek water.

2. *Virulent character of the blood serum of the horse, two to seven hours*[10] *after intravenous injection of the animal with hog-cholera virus.*

Experimental evidence indicates that a portion of blood secured from the horse two to four hours after the animal has received 85 to 200 cc. of hog-cholera serum intravenously will manifest virulent properties when injected intravenously into the healthy hog. The following data relate to this phase of the work:

On July 17, 1908, 11 A. M., horse No. 3, bay gelding in good condition, was injected intravenously with 150 cc. of hog-cholera serum (Norwood strain). The usual symptoms as described above were exhibited. Heart at first greatly accelerated, later depressed; respiration accelerated and difficult; peristalsis violently active. The temperature of the animal four hours after the injection was 103 degrees. Four hours after the injection two liters of blood were drawn, and twenty-four hours after five liters were obtained.

On July 18, 1908, hog No. 9, small red Duroc-Jersey, weight 30 pounds, was injected in the ear vein with 5 cc. of horse No. 3, 4-hour serum. On July 23, five days after inoculation, this pig showed loss of appetite, languor, and thermal reaction of 105.8 degrees. (See table 4.) After the fifth day the animal refused all food, remained in a corner, was constipated and became greatly emaciated. On the fourteenth day after inoculation, August 1, the pig being moribund, was chloroformed, bled from the carotid artery, and autopsy made. Typical lesions of hog cholera were found. On the ventral portion of the body were purple discolorations of the skin; blood extravasations in the subcutaneous tissue; portion of the dependent lobes of both lungs were congested and hepatized; spleen soft and gorged with blood; liver and kidneys normal; the inguinal, mediastinal and mesenteric lymphatic glands enlarged and hemorrhagic. Evidences of ulceration were present in the cæcum. (See plate 6.)

As a means of control or check on the above experiment with the 4-hour horse serum, the following inoculation experiment was conducted with the original Norwood hog-cholera serum:

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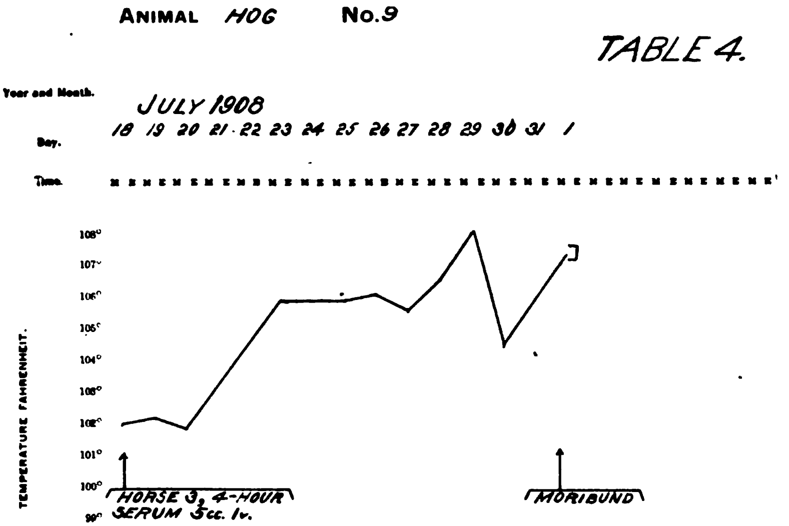
[10] Hereafter, in this bulletin, "2-hour horse serum," "4-hour horse serum" or "24-hour horse serum" will be used to indicate that the serum in question was obtained from the horse two hours, four hours or twenty-four hours after the animal was injected intravenously with hog-cholera serum.

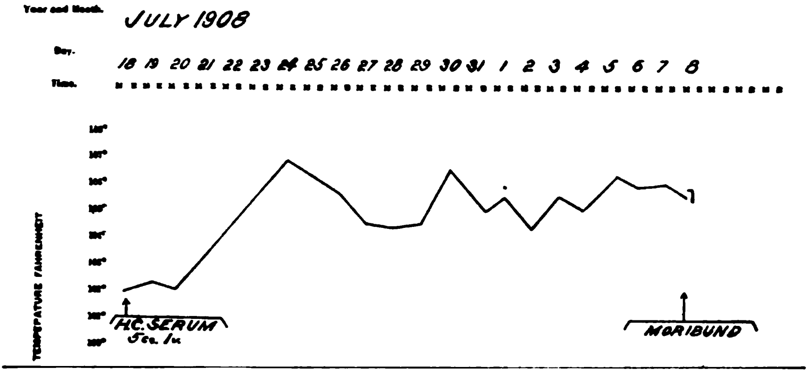
Hog No. 10, belonging to the same litter with hog No. 9, on July 18, 1908, was injected in the ear vein with 5 cc. of the same lot of hog-cholera serum which was used in the preparation of the 4-hour horse serum, horse No. 3. Five days after inoculation, July 23, this animal manifested loss of appetite and constipation. The usual symptoms became gradually more pronounced for the next few days, but by August 30 the appetite had returned and the pig became brighter. On August 5, however, typical symptoms of acute cholera were again present, and on August 8, twenty-one days after inoculation, the animal, being moribund, was chloroformed, bled, and autopsy performed. (See table 5.) Typical lesions of cholera were found, although not as severe pathological conditions were present in proportion to the duration of infection in each case as those which were found in hog No. 9.

TABLE 4.



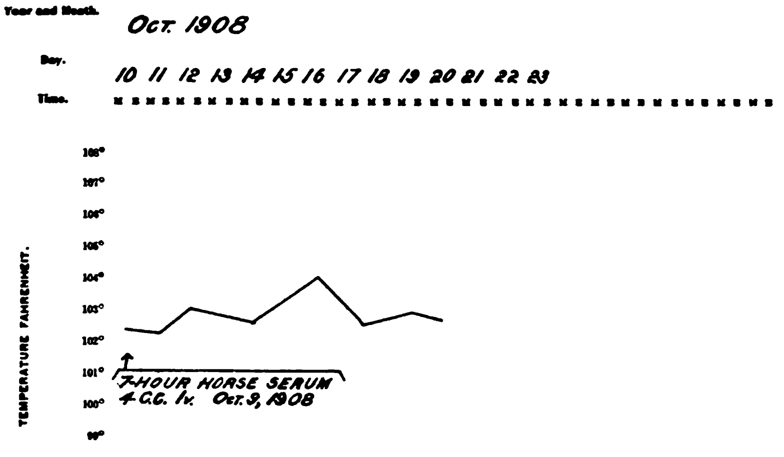
ANIMAL HOG No. 10

TABLE 5



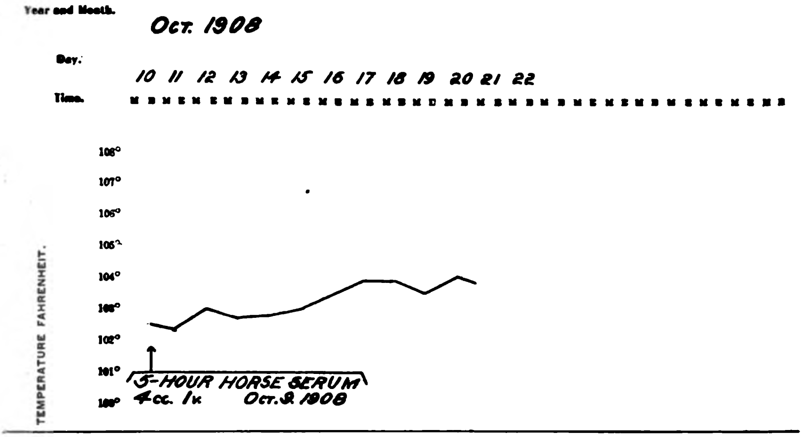
ANIMAL HOG No. 28

TABLE 6



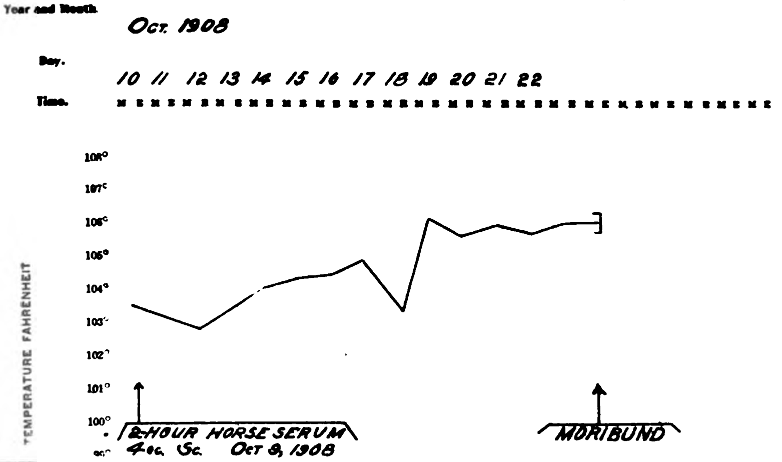
ANIMAL HOG **No.** 29

TABLE 7.



ANIMAL HOG **No.** 30

TABLE 8



On October 9, 1908, hogs Nos. 28, 29 and 30 were injected subcutaneously with 2- to 7-hour horse serum. The results of this test indicate the virulent nature of 2-hour horse serum. This experiment also logically shows that attenuative changes in the hog-cholera virus take place after a residence of from five to seven hours in the blood of the horse.

The temperature curves of hogs Nos. 28, 29 and 30 are shown in tables 6, 7 and 8. The following appended notes give the details of the experiment:

Hogs Nos. 28, 29 and 30, weight about 30 pounds each, all belonging to the same litter, on October 9, 1908, were treated as follows: Hog No. 28, injected intravenously with 4 cc. 7-hour horse No. 3 serum; hog No. 29, injected intravenously with 4 cc. 5-hour horse No. 3 serum; hog No. 30, injected intravenously with 4 cc. 2-hour horse No. 3 serum.

Hog No. 28, seven days after inoculation with 7-hour horse serum, showed a temperature reaction of 1½ degrees. (See table 6.) No other deviations from normal conditions occurred and the animal is at present in healthy condition.

Hog No. 29, seven days after receiving the 5-hour horse serum, showed a slight rise in temperature (see table 7), which continued for several days. On October 19, nine days after inoculation, hog No. 29 appeared to have a slight chill and showed loss of appetite. By August 21, twelve days after inoculation, the animal was normal in every way and is at present in good condition.

Hog No. 30, on October 14, five days after inoculation, had a temperature of 104 degrees, which gradually rose on October 17 to 104.8 degrees. (See table 8.) The animal showed loss of appetite, constipation, and the usual symptoms of hog cholera. On October 19, the temperature, after having dropped to 103.4 degrees on the preceding day, reached 106 degrees. The symptoms steadily became more pronounced, and on October 24, fifteen days after inoculation, hog No. 30 being moribund, was chloroformed, bled, and autopsy performed. The lesions were those of the acute type of hog cholera.

When one considers that the hog-cholera virus is introduced into the horse in the rough proportion of 150 cc. of virus to 30,000 cc. or more of horse blood, making a dilution of 1 part of hog-cholera virus to 200 or more parts of horse blood, and that the 2- to 4-hour horse serum will produce the typical form of the disease in a healthy hog, it may be theorized that for the first few hours after the injection of the animal, the hog-cholera virus or organism rapidly multiplies in the body fluid of the horse. The results obtained from inoculation of hogs Nos. 28 and 29 with 7- and 5-hour horse serum, respectively, make evident the fact that after five to seven hours' residence in the blood of the horse the hog-cholera virus undergoes attenuative changes. In the following pages it will be seen from a number of series of experiments that 24-hour horse serum is more attenuated in virulence. Therefore we may assume that this attenuation is not due to mere dilution of the hog-cholera virus in the horse's blood, but that it is the result of physiological activity and antagonistic forces; a process of attenuation which should be found to be uniform and constant to a greater or lesser degree.

The above experiment is of considerable importance in that it tends to prove that 2- to 4-hour horse serum contains the virus in sufficient quantity and strength to produce the disease in the acute form. This experimental evidence may be of some aid in determining the nature of the organism which is the specific cause of the disease.

3. *Intravenous versus subcutaneous inoculation with 4-hour horse-serum hog-cholera virus.*

The above experiments indicate the infectious nature of 4-hour horse serum when injected intravenously into the healthy hog. An attempt was then made to produce the disease by injecting 4-hour horse serum subcutaneously. On September 2, 1908, hog No. 22 was injected subcutaneously with 4 cc. of horse No. 4, 4-hour serum. On September 4, 1908, hog No. 23 received subcutaneously 4 cc. of horse No. 3, 4-hour serum. No apparent results followed the above inoculations, except a possible temperature reaction in the case of hog No. 23 on the fifth day after inoculation. (See tables 37 and 38.)

On September 15, hogs Nos. 22 and 23 were each injected intravenously with 5 cc. of the same respective lots of 4-hour horse serum which they had previously received subcutaneously. On the same date, hog No. 26, a control, was injected in the ear vein with 5 cc. of horse No. 3, 4-hour serum. Hogs Nos. 22 and 23 remained in a normal condition, while hog No. 26, the control, showed the usual symptoms of the disease after an incubation period of seven days, and became moribund on the twelfth day after inoculation.

Thus it appears from this preliminary work that 4-hour horse serum contains highly virulent properties when injected intravenously into the healthy hog, while the subcutaneous injection of the same does not produce the disease. Furthermore, the subcutaneous inoculation of the 4-hour horse serum is not inert, because it shows protective properties. (See plate 13.)

This phase of the work is far from being completed. Determinations relative to pathogenetic and protective properties must be made of horse serum drawn at close intervals of time from one-half hour to several hours after the animal has received the hog-cholera virus in the blood. It is obvious that this work is of considerable practical value.

The thought suggests itself that, in case a satisfactory vaccine cannot be obtained from horse serum, this part of the method might possibly be utilized in the simultaneous method. Assuming that conclusive investigations should prove that 2- to 4-hour horse serum maintains a constant virulent character, then this horse serum virus might be substituted for the hog-cholera serum virus in the preparation of "Dorset's Hog Cholera Vaccine." Such a substitution would tend to reduce the expense of the simultaneous method.

4. *Attenuated character of hog-cholera virus after twenty-four hours or more residence in the blood of the horse.*

The following data, in comparison with the intravenous injection of 4-hour horse serum, show the results obtained by the same method of inoculation when 24-hour horse serum is employed:

Hog No. 245, weight 60 pounds, on February 26, 1907, was injected in the ear vein with 10 cc. of 24-hour horse serum. (Gray gelding, blood drawn twenty-four hours after being injected in the jugular vein with 150 cc. of mixed hog-cholera serum.) Hog No. 245 received subcutaneously at the same time 10 cc. of the same virus. On March 4 this animal received intravenously a second injection of the same lot of 24-hour horse serum. Five days after the second injection the animal showed a marked thermal reaction, the temperature remaining between 105 degrees and 106 degrees for four days, after which it became normal. This pig showed no loss of appetite or other symptoms at any time during the treatment. On April 15 he weighed 82 pounds, showing a gain of 22 pounds since the beginning of the treatment on February 26.

Hog No. 247, weight 61 pounds on February 26, 1907, received 10 cc. intravenously and 10 cc. subcutaneously, of 24-hour horse serum. On March 4 he was injected the second time intravenously with 24-hour horse serum. This animal showed no disturbance in temperature and exhibited no symptoms whatever as a result of the treatment; during the first eleven days of the treatment he gained 2½ pounds.

Hog No. 248, weight 46½ pounds, on February 26, 1907, received intraperitoneally 10 cc. and subcutaneously 10 cc. of 24-hour horse serum. Seven days afterward he received intravenously 10 cc. more of the same material. During the eleven days of treatment the animal gained 7½ pounds in weight. He showed no untoward symptoms as a result of the inoculations, although later the animal died of acute hog cholera after natural exposure.

The temperature charts of hogs Nos. 245, 247 and 248 appear in tables 22, 24 and 25.

The statement should be made that these experiments are not conclusive proof that 2-hour horse serum injected subcutaneously in small quantities and 4-hour horse serum injected intravenously always produce the disease in the healthy hog, and that 5- to 7-hour horse serum subcutaneously and 24-hour horse serum intravenously injected never cause infection. The great variation among individual animals, and the peculiar idiosyncrasies of swine particularly, preclude such a definite assertion.

5. *Protective properties of experimental horse-serum hog-cholera vaccine.*

The production of a satisfactory hog-cholera vaccine constitutes the practical problem which is included in this investigation. The attempt is being made to produce such a vaccine by passing the hog-cholera virus through the horse. A vaccine prepared according to such a method, providing it were efficient, would prove to be highly practical because of its comparative inexpense. A rough estimate of the actual cost of horse-serum vaccine will readily show that it can be prepared at a nominal expense. A very liberal estimation would place its cost at from one-third to one-half of that involved in the manufacture of the vaccine used in the simultaneous method.

The results so far obtained are strictly those from laboratory and experimental work and are not sufficiently confirmed to warrant the assumption that they are definitely conclusive. The experiments must be verified by repeated observations of the same under various conditions before definite deductions can be drawn.

The results of the following series of experiments tend to demonstrate that under certain conditions healthy hogs can be successfully vaccinated by the use of the method.

On January 18, 1907, hogs Nos. 235, 236 and 237 were treated as follows:

Hog No. 235 was injected with 10 cc. intravenously and 10 cc. subcutaneously of 24-hour donkey serum; hog No. 236, 24-hour donkey serum, 10 cc. intravenously, and 48-hour donkey serum, 10 cc. subcutaneously; hog No. 237, 48-hour donkey serum, 10 cc. subcutaneously, and 72-hour donkey serum, 10 cc. subcutaneously. In none of these hogs was any apparent reaction noted as a result of the vaccination.

On January 28, ten days after vaccination, hogs Nos. 235, 236 and 237, together with hog No. 238, an untreated control animal, were exposed to the disease by being placed in an infected pen and by being fed viscera from hog No. 234. Hog No. 234 was chloroformed, bled and posted on January 22, having had an acute case of the disease of twelve days' duration.

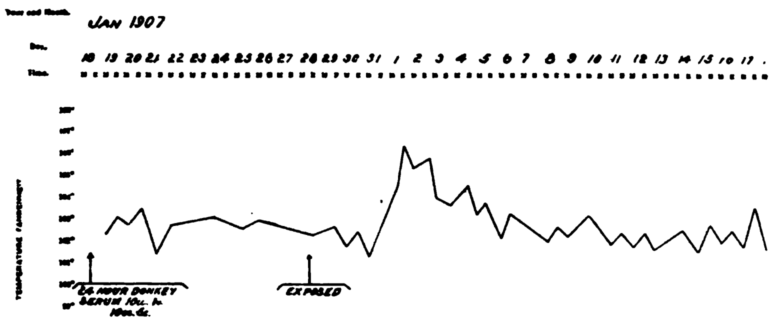
Of this series of four hogs, the control animal, No. 238, after five days' incubation period, exhibited severe symptoms of the disease. On the fifth day the temperature rose to 107. (See table 12.) The animal refused to eat and became constipated and emaciated. On the eighth day after exposure this hog, being moribund, was chloroformed, bled and posted. The head, ears and ventral portion of the body showed a diffuse pink color. Autopsy showed blood extravasations in the subcutaneous and muscular tissues, lymphatic glands enlarged and hemorrhagic, kidneys ecchymotic and petechied. Several small ulcers were present in the cæcum and colon. Vaccinated hog No. 235, which belonged to the same litter with hog No. 238, on the fifth day after exposure showed a rise of temperature to 106 degrees. (See table 9.) This animal, however, did not suffer loss of appetite or show any symptoms of disease, other than a thermal reaction. After four days the temperature became normal. Twenty-two days after vaccination the animal was temporarily released.

Hog No. 236 showed no temperature reaction after exposure, and remained throughout in a normal condition. (See table 10.) Twenty-two days after exposure the animal was temporarily released.

Hog No. 237, which received the 48- and 72-hour donkey serum, on the eighth day after exposure showed a temperature of 105.2 degrees. (See table 11.) On the twelfth day after exposure symptoms of the disease appeared. On the twenty-first day after date of exposure this animal was found dead. Autopsy showed lesions of hog cholera less severe in type than those found in hog No. 238. The results of the above experiment appear in tabulated form in table 13.

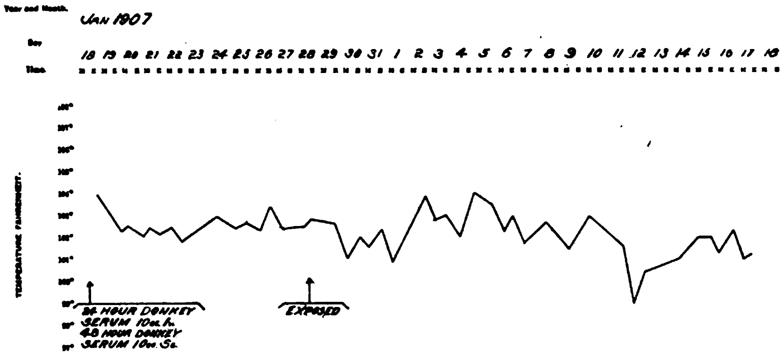
ANIMAL HOG No.235

TABLE 9



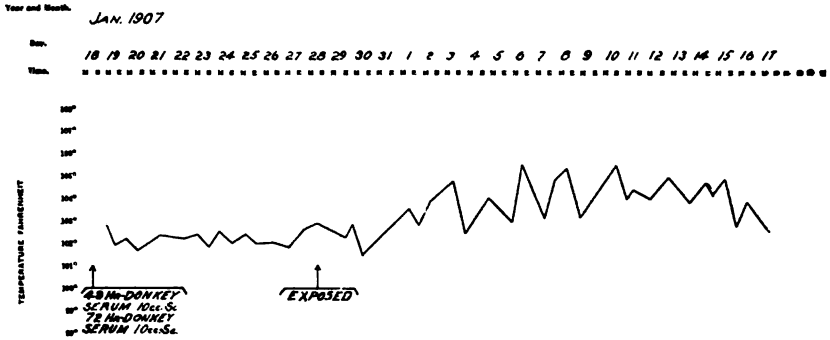
ANIMAL *Hog* **No.** 236

TABLE 10



ANIMAL *Hog* **No** 237

TABLE 11



ANIMAL *Hog* **No.** 238 (CONTROL)

TABLE 12

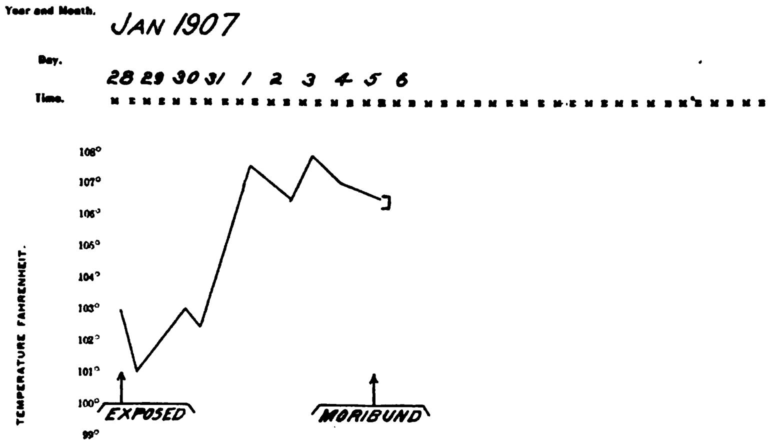


TABLE 13.
EXPERIMENTAL VACCINATION.

Hog No.	Character of vaccine injected.	Method of vaccination.	Date of vaccination.	Period of time between vaccination and exposure.	Result of exposure.
235	24-hr. donkey serum 24-hr. donkey serum	10 cc. Iv.* 10 cc. Sc.*	Jan. 18, 1907 Jan. 18, 1907	10 days	Did not take disease.
236	24-hr. donkey serum 48-hr. donkey serum	10 cc. Iv. 10 cc. Sc.	Jan. 18, 1907 Jan. 18, 1907	10 days	Did not take disease.
237	48-hr. donkey serum 72-hr. donkey serum	10 cc. Sc. 10 cc. Sc.	Jan. 18, 1907 Jan. 18, 1907	10 days	Found dead from hog cholera 21 days after exposure.
238	Control	....	....	....	Moribund; bled and posted 10 days after exposure.

* Iv. = Intravenously; Sc. = Subcutaneously.

These hogs were exposed January 28, 1907, by being fed viscera of cholera hog No. 234.

From this series, the suggestion follows that hogs Nos. 235 and 236, which received the 24-hour donkey-serum vaccine, were protected against the disease by the vaccination. Additional proof of this is found in the fact that hog No. 235 showed some result of exposure coincident with the incubation period exhibited in hog No. 238. Hog No. 235 was therefore in all probability protected, not by natural, but by acquired, immunity. The successful vaccination of hog No. 236, which received the same treatment as hog No. 235, furnishes additional proof of the positive result. The value of the experiment is also logically strengthened by the presence of a less severe type of the disease in hog No. 237, which received subcutaneously 48-hour donkey-serum vaccine, as compared with that which appeared in the control, hog No. 238.

The results following the treatment of another series of eight hogs with horse-serum vaccine are shown in table 14.

Attention should be called to the fact that hogs Nos. 241 and 242 both died before or at the time of exposure. In hog No. 241, which died before exposure, no lesions could be found. Some symptoms of rheumatism were noted, however, while the animal was under treatment. Hog No. 242 was found dead the next morning after eating the infected viscera. On autopsy no lesions were found, except a pronounced congested condition of the mucous membrane of the alimentary tract. Some of the viscera which were fed had been kept in the ice-chest for several weeks and it might appear that hog No. 242 died from ptomain poisoning.

TABLE 14.

EXPERIMENTAL VACCINATION.

Hog No..	Vaccine injections...	First injection.	Second injection.	Third injection.	Time between last injection and exposure.	Result.
		Material injected; date.	Material injected; date.	Material injected; date.		
239	3	February 18. 24-hr. horse serum, 10 cc. Iv. and Sc.*	February 26. 24-hr. horse serum, 10 cc. Ip.	March 4. 24-hr. horse serum, 10 cc. Iv.	12 days	Did not take the disease.
240	3	February 18. 24-hr. donkey serum, 20 cc. Sc.	February 26. 24-hr. horse serum, 20 cc. Iv. and Sc.	March 4. 24-hr. horse serum, 5 cc. Iv.	12 days	Did not take the disease.
241	2	February 26. 24-hr. horse serum, 20 cc. Ip.† and Sc.	March 4. 24-hr. horse serum, 20 cc. Iv. and Sc.			Found dead March 16, before exposure.
242	2	February 26. 24-hr. horse serum, 10 cc. Iv. and Sc.	March 4. 24-hr. horse serum, 20 cc. Iv.			Found dead March 13.
243	Control; no treatment.					Moribund. Bled and posted March 30.
244	2	February 26. 24-hr. horse serum, 20 cc. Sc. and Ip.	March 4. 24-hr. horse serum, 10 cc. Iv.		12 days	Did not take disease.
245	2	February 24. 24-hr. horse serum, 20 cc. Sc. and Iv.	March 4. 24-hr. horse serum, 10 cc. Iv.		12 days	Did not take disease.
246	Control; no treatment.					Moribund, March 26. Bled and posted.
247	2	February 24. 24-hr. horse serum, 20 cc. Iv. and Sc.	March 4. 24-hr. horse serum, 10 cc. Iv.		12 days	Did not take disease.
248	2	February 24. 24-hr. horse serum, 20 cc. Ip. and Sc.	March 4. 24-hr. horse serum, 10 cc. Iv.		12 days	Found dead March 30.

* Iv. = Intravenously; Sc. = Subcutaneously. † Ip. = Intraperitoneally.

These hogs were exposed March 16, 1907, by being fed viscera from hogs dead from cholera, and by being placed in an infected pen.

With the exception of hogs Nos. 241 and 242, both of which apparently died from other causes than hog cholera, all of the vaccinated hogs, except hog No. 248, withstood infection. This hog was evidently not protected by the vaccination. In this connection it should be noted that hog No. 244, while exhibiting a marked degree of immunization, did not gain in weight during and after exposure, as did most of the others. Hogs Nos. 243 and 246, the two control animals, both contracted the disease and were moribund at the end of fourteen and ten days, respectively, after exposure. In this experiment practically 83⅓ per cent. of the vaccinated hogs withstood infection. The weight and general condition of each of the animals in the above experiment at various times is given in table 15:

TABLE 15.

Hog No.	Vaccination treatment—No. of injections.	Weight March 1. *lbs.*	Weight March 7. *lbs.*	Weight and general condition April 15.
239	3	75½	87	90 lbs. In good condition.
240	3	26½	31⅛	Weight not recorded. In good condition.
241	2	38	50	Dead (not cholera).
242	2	46	54	Dead (not cholera).
243	Control	27½	34½	Dead (cholera), March 30.
244	2	29	33½	33 lbs. Eating well, but not gaining in weight.
245	2	60	68	90 lbs. In fine condition.
246	Control	....	....	Dead (cholera), March 26.
247	2	61	69½	Weight not recorded. In good condition.
248	2	46½	53	Dead (cholera).

The temperatures of the above hogs during protective inoculations and subsequent exposure are shown in tables 16 to 25:

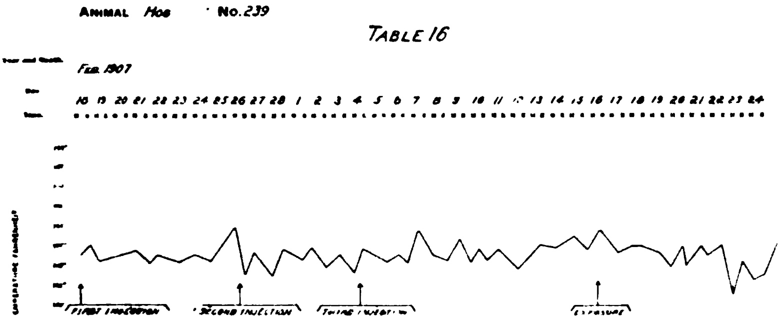
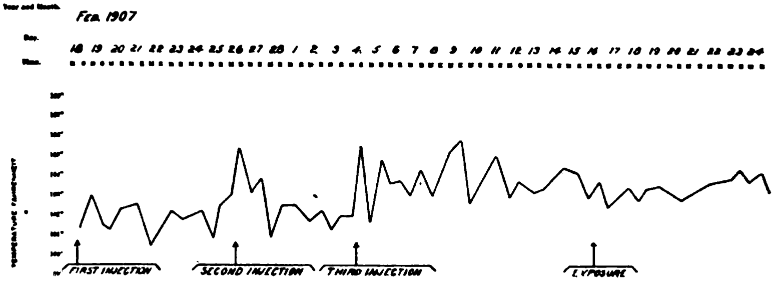


TABLE 16

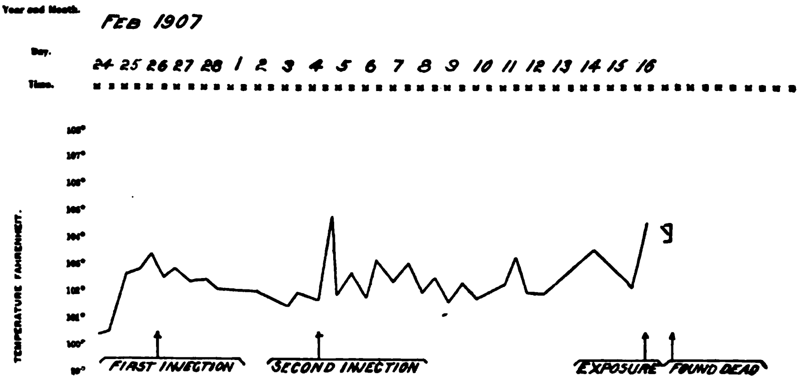
ANIMAL Hog No.240

TABLE 17



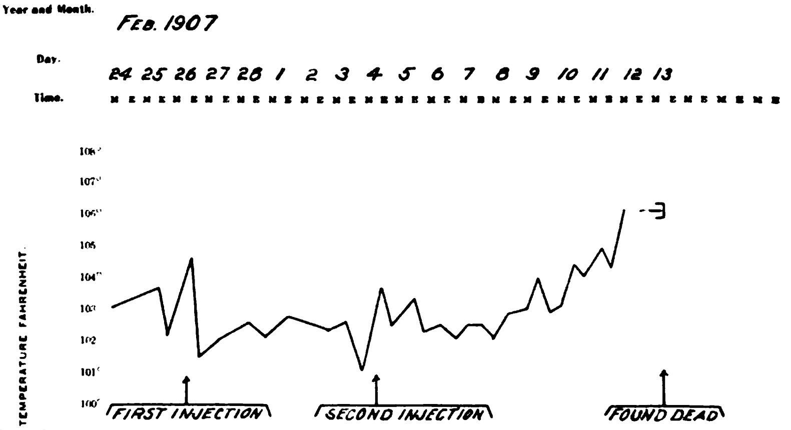
ANIMAL Hog No.241

TABLE 18



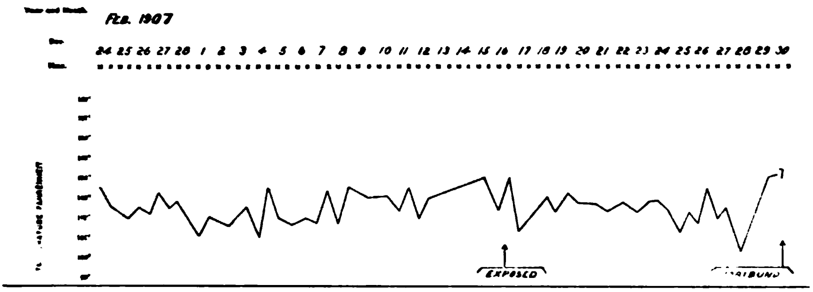
ANIMAL Hog No.242

TABLE 19



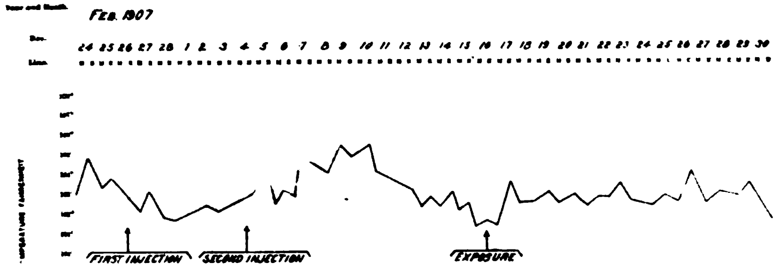
ANIMAL HOG No. 243 (CONTROL)

TABLE 20



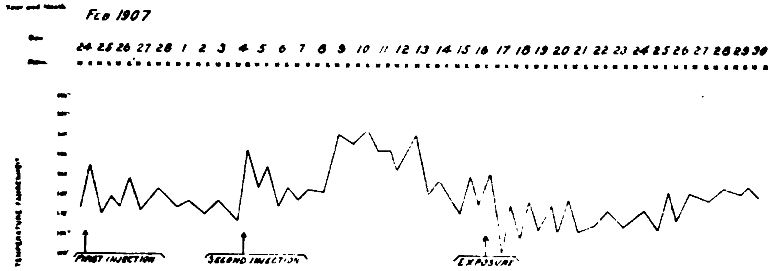
ANIMAL HOG No. 244

TABLE 21



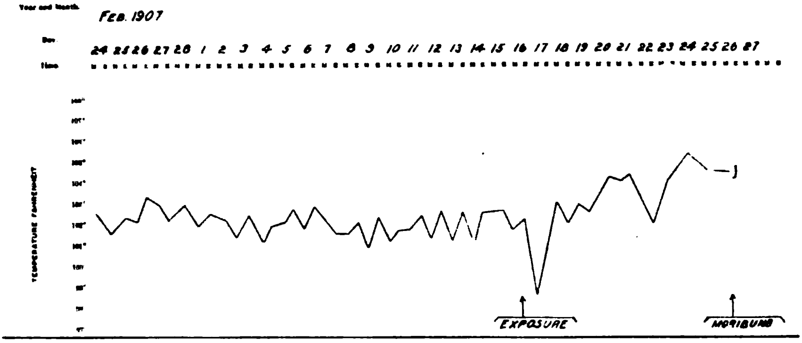
ANIMAL HOG No. 245

TABLE 22



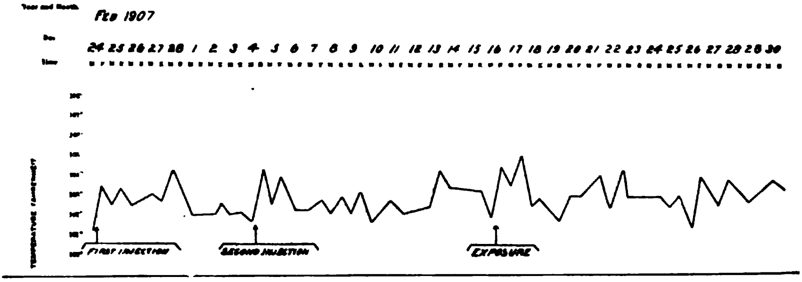
ANIMAL HOG NO. 246

TABLE 23



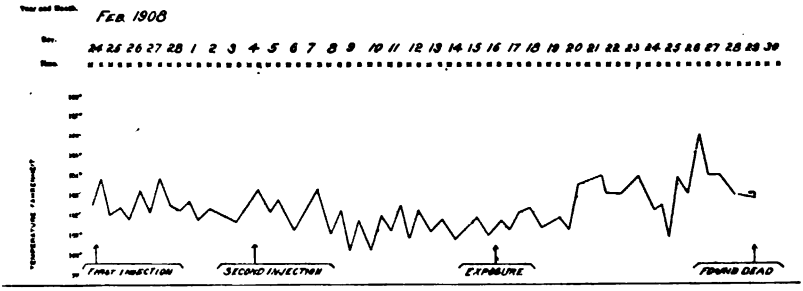
ANIMAL HOG NO. 247

TABLE 24



ANIMAL HOG NO. 248

TABLE 25



Experience tends to show that 24-hour horse-serum vaccine is not constant as to its protective power when injected subcutaneously in small quantities. The following experiment, indicated in table 26, shows the results obtained from the subcutaneous vaccination of a series of seven healthy hogs with small doses of 24-hour horse-serum vaccine:

TABLE 26.

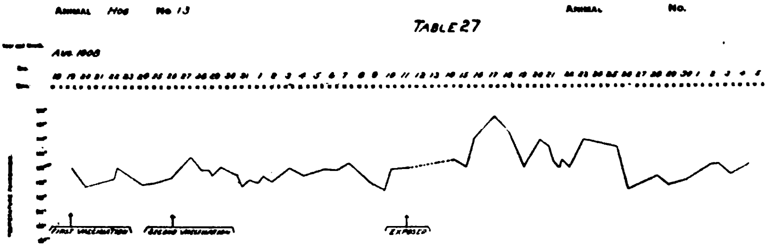
EXPERIMENTAL VACCINATION.

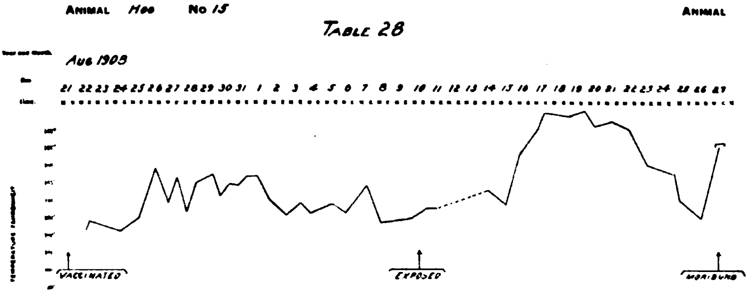
Hog No.	No. of injections of vaccine....	Date and material used, first injection.	Date and material used, second injection.	Time between last injection and exposure.	Result of exposure.
13	2	Aug. 19, 1908. 24-hr. horse 3. 3 cc. Sc.	Aug. 26, 1908. 24-hr. horse 3. 5 cc. Sc.	16 days	Did not take the disease.
15	1	Aug. 21, 1908. 24-hr. horse 4. 4 cc. Sc.		20 days	Moribund September 27. Chloroformed, bled, and posted.
16	1	Aug. 29, 1908. 24-hr. horse 3. 3 cc. Sc.		12 days	Found dead from cholera, September 28, 1908.
17	1	Aug. 24, 1908. 24-hr. horse 3. 3 cc. Sc.		12 days	Moribund September 27. Chloroformed, bled, and posted.
18	1	Aug. 29, 1908. 24-hr. horse 3. 3 cc. Sc.		12 days	Morbid September 27. Chloroformed, bled, and posted.
19	1	Sept. 2, 1908. 30-hr. horse 4. 4 cc. Sc.		8 days	Did not take the disease.
20	Control.				Found dead from cholera, September 26, 1908.
21	1	Sept. 2, 1908. 30-hr. horse 3. 3 cc. Sc.		8 days	Did not take the disease.
24	Control.				Found dead from cholera, October 5, 1908.

With the exception of hog No. 13, which was exposed September 11, 1908, all these animals were exposed September 10, 1908, by being injected subcutaneously with 3 cc. each of mixed hog-cholera serum from hogs Nos. 6, 9, 10 and 11.

In the above experiment $42\frac{6}{7}$ per cent. of the vaccinated hogs were saved. All of the vaccinated hogs manifested a strong thermal reaction five to seven days after the exposure, which consisted of the subcutaneous injection of virulent hog-cholera serum. Hogs Nos. 13, 19 and 21, however, all of which showed a temperature reaction of from 106 degrees to 108 degrees, remained bright and active and soon regained their normal condition. In plate 9 is shown a photograph of these three hogs, together with the dead control, hog No. 24, which died on October 5. Hogs Nos. 13, 19 and 21 are at present in good, healthy condition. Both control animals, hogs Nos. 20 and 24, upon *post-mortem* showed typical lesions of acute hog cholera. See half-tone showing autopsy of hog No. 24, plate 10.

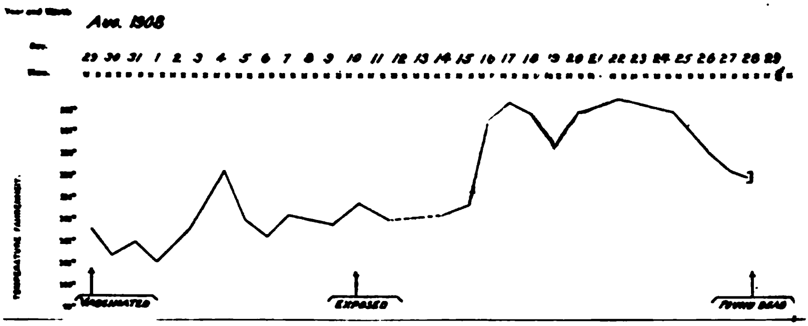
In connection with the above experiment, attention should be called to the following facts: (1) A relatively small quantity of horse-serum vaccine was used in each vaccination; (2) the experimental animals were young pigs, weighing approximately thirty pounds each, which are much more difficult to immunize than are larger hogs; (3) the exposure was rigid, each animal receiving a hypodermic injection of highly virulent serum.





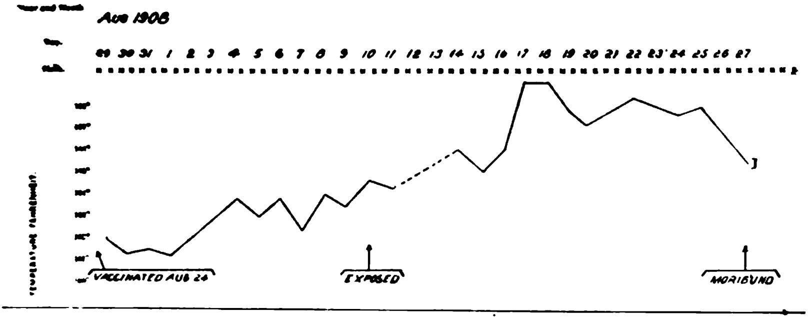
ANIMAL Hog No. 16

TABLE 29



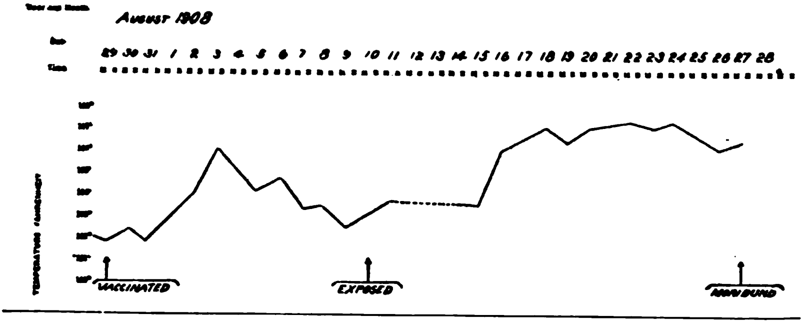
ANIMAL Hog No. 17

TABLE 30



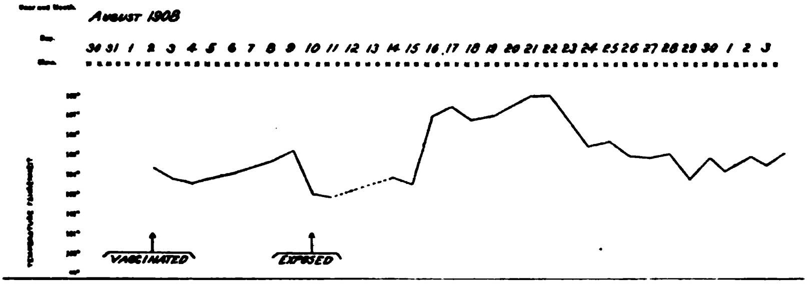
ANIMAL Hog No. 18

TABLE 31



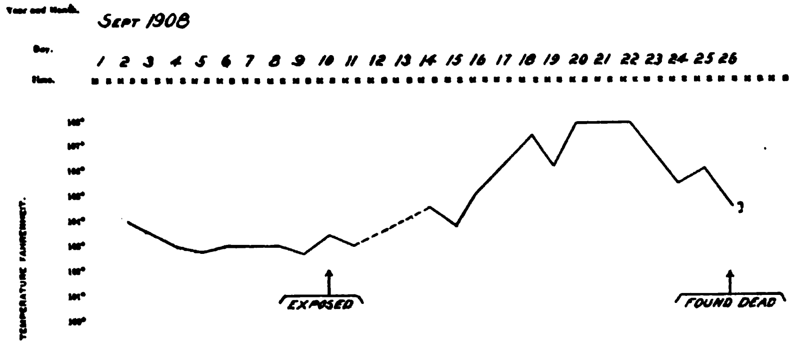
ANIMAL Hog No. 19

TABLE 32



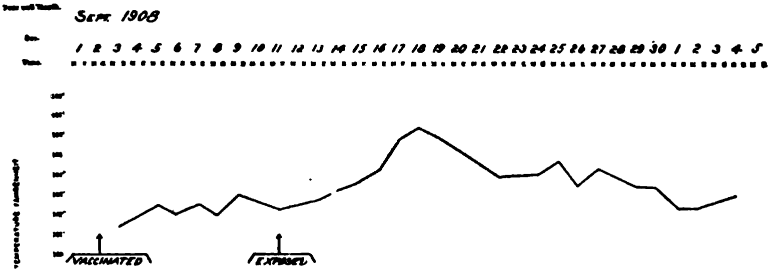
ANIMAL Hog No. 20 (CONTROL)

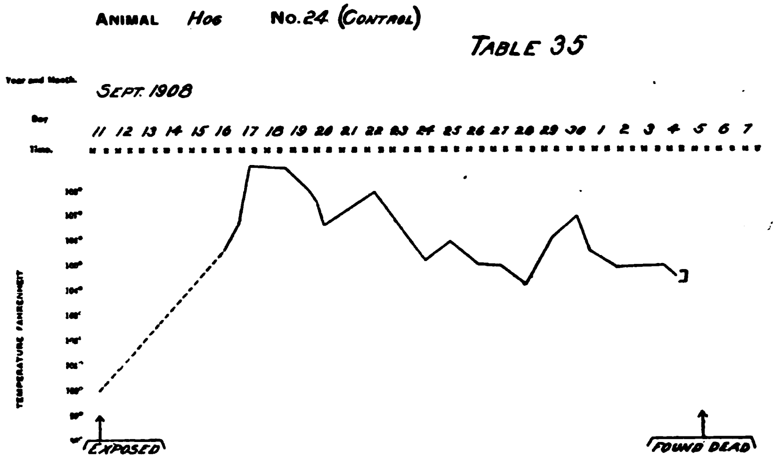
TABLE 33



ANIMAL Hog No. 21

TABLE 34



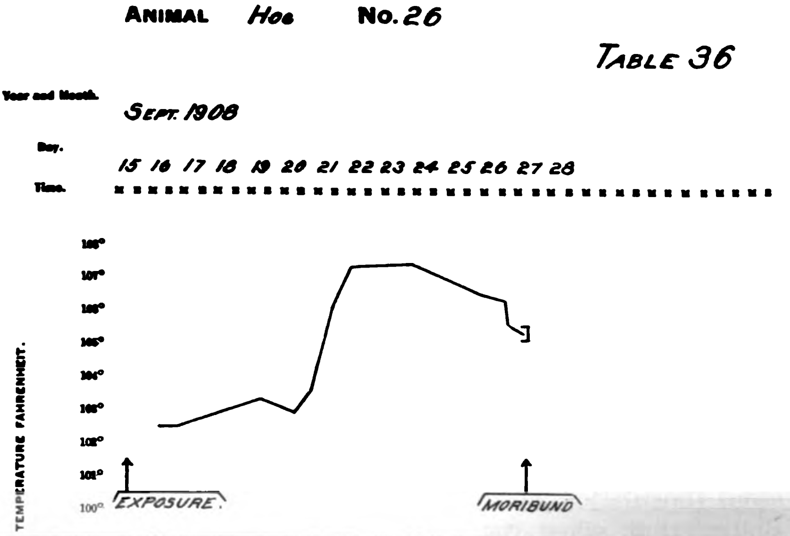


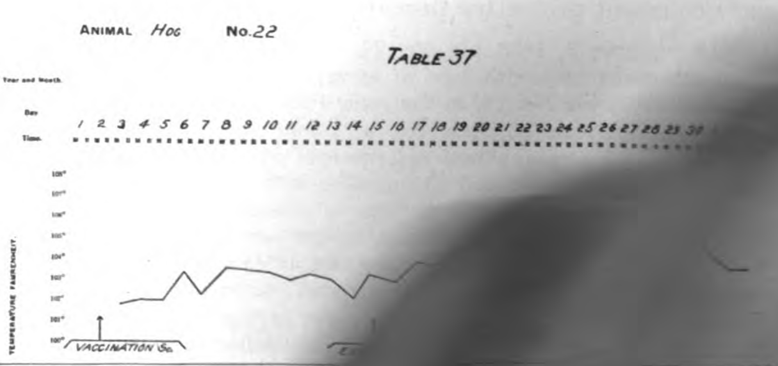
A glance at the above temperature charts of the hogs described in the above experiment will show that an apparent temperature reaction followed the vaccination in most cases. It will be noticed that hog No. 21 manifested no evident rise in temperature. Hogs Nos. 13, 15, 16, 17, 18 and 19 all showed distinct temperature reactions five to seven days after vaccination.

A general survey of the whole work with 24-hour horse-serum vaccine indicates that it is not entirely constant and uniform in its protective action. The following preliminary experiment (referred to under "Intravenous *versus* Subcutaneous Inoculation with Horse-serum Virus") suggests the possibility that when the hog-cholera virus is subjected to a shorter residence in the horse than twenty-four hours it may show constant protective properties:

On September 2, 1908, pig No. 22, weight about 30 pounds, was injected subcutaneously with 4 cc. of horse No. 4, 4-hour serum. On September 4, 1908, pig No. 23, in the same litter, with pig No. 22, received subcutaneously 4 cc. of horse No. 3, 4-hour serum. Neither of these animals showed any apparent disturbances after inoculation. On September 15, hogs Nos. 22 and 23, together with control hog No. 26, were injected intravenously, each with 5 cc. of 4-hour horse serum. Hog No. 26, the control, received horse No. 3, 4-hour serum. Neither of the pigs which received the previous subcutaneous injection manifested any deviations from normal conditions as a result of the intravenous injection. Hog No. 26, the control, however, after five days contracted a severe case of the disease and became moribund on September 27, twelve days after inoculation. (See temperature chart, table 36.) Lesions in the heart and lungs and kidneys found in the *post-mortem* of this animal appear in plates 11 and 12.

Hogs Nos. 22 and 23 on September 26 were placed in an infected pen with sick hogs, Nos. 26 and 8. They were fed fresh viscera of hogs Nos. 17 and 18, which had died from cholera. Both animals showed a rise in temperature of from two to three degrees five days after eating the infected viscera. (See temperature charts, tables 34 and 35.) No other indications of a disturbance followed. These two animals are at present under constant exposure in an infected pen and appear heathy in every way. The photograph below (plate 13) shows hogs Nos. 22 and 23, on October 5, together with dead control hog No. 26, and chronic case, hog No. 8, with which they had been confined.





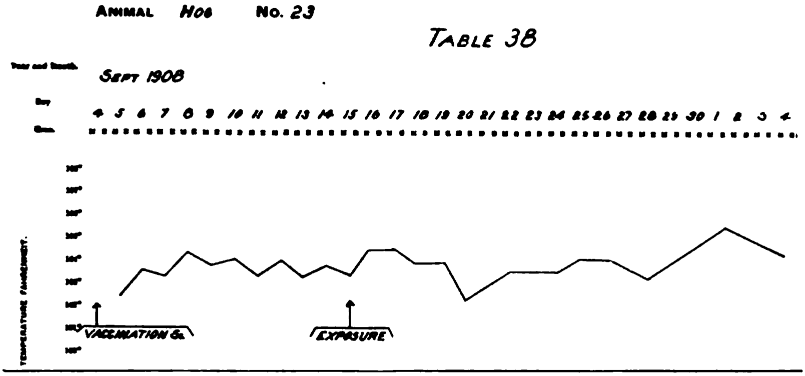


TABLE 38

It appears logical to continue the experiments with horse-serum hog-cholera vaccine for the purpose of determining whether some period of residence in the horse less than twenty-four hours will not sufficiently attenuate the hog-cholera virus so that it will exhibit protective properties with more reasonable uniformity than does the 24-hour serum vaccine. The results of these preliminary experiments suggest that under some conditions 4-hour horse serum is pathogenic to the hog, while a residence of twenty-four hours in the horse tends to modify these pathogenic properties of the virus to such an extent that it does not produce the disease in a healthy hog. The foregoing experiments show that 2-hour horse serum produces the disease when injected in small quantities subcutaneously; and that 4-hour horse serum does not cause infection when injected in small quantities subcutaneously, but does produce acute hog cholera when injected intravenously in reasonable doses. It has also been shown that 5-hour and 7-hour horse serum does not produce infection when injected subcutaneously. Moreover, the subcutaneous inoculation of 4-hour horse serum uniformly produces immunity, according to preliminary experimentation. The 24-hour horse serum has been shown quite definitely to be non-virulent in character and attenuated to such a degree that its vaccinating properties are not constant. If such conditions are true the practical question to be solved is, After what period of residence in the circulatory system of the horse does the hog-cholera virus become most efficient as a vaccine without producing infection? The problem resolves itself into the correct standardization of the horse-serum vaccine.

In connection with this work a limited amount of field-work is at present in progress in various parts of the state of Kansas. Extensive experimentation must be conducted and considerable time must necessarily be employed to definitely prove the reliability of the method of vaccination.

VII.

DURATION OF IMMUNITY.

Experimental evidences warrant the statement that a hog once immunized to the disease of hog cholera will retain the protection for a period of several months. Thus the successfully vaccinated or immunized hog may be kept with no risk of infection for a period long enough to fatten and prepare the animal for market. The following data relative to this point are given as experimental evidence:

Hog No. 1, grade English Yorkshire, female, weight about 60 pounds, received the following treatments: January 12, 1908, injected Sc. 8 cc. bay mare 48-hr. serum, which was drawn June 29, 1907; January 31, 1907, injected Sc. 5 cc. crippled mare 24-hr. serum, drawn March 25, 1907; February 17, 1908, injected Sc. 5 cc. gray horse 24-hr. serum, drawn April 4, 1907; February 29, 1908, injected Sc. 2 cc. hog-cholera serum, hog No. 259, drawn May 16, 1907; March 30, 1908, injected Sc. 6 cc. hog-cholera serum, hog No. 264, drawn May 30, 1907; April 10, 1908, fed viscera and blood from dead hogs, Riley strain; July 25, 1908, placed in infected pen with hogs Nos. 9 and 10; August 19, 1908, injected Sc. with 5 cc. horse No. 3 4-hour serum; September 28, 1908, fed viscera and placed with hogs sick and dying from hog cholera.

Hog No. 2, grade Duroc-Jersey, boar, weight about 80 pounds, received the following treatments: January 12, 1908, injected Sc. with 8 cc. bay mare 6-hour serum, drawn April 14, 1907; May 13, 1907, hog No. 264 received Sc. 10 cc. of bay mare 6-hour serum, and under conditions of isolation eight days after developed acute hog cholera. Hog No. 264 died on the seventeenth day after inoculation. Hog No. 2 showed rise of temperature (see table 39) and loss of appetite five days after inoculation, but after eleven days again appeared normal. On January 31 and February 17, hog No. 2 received injections Sc. with the same material with no apparent effects. February 29, hog No. 2 received Sc. 0.2 gm. dried hog-cholera serum from hog No. 264, drawn May 30, 1907; March 31, hog No. 2 received Sc. 6 cc. hog-cholera liquid serum from hog No. 264. This animal received the same exposures as hog No. 1, described above.

Hogs Nos. 3 and 4, grade Yorkshire, weight about 40 pounds each: On February 29, hog No. 3 received Sc. 0.2 gm. dried hog-cholera serum from hog No. 259, drawn May 16, 1907. Evidences of cholera followed the inoculation. On the same date hog No. 4 received Sc. 2 cc. of hog-cholera serum from hog No. 264, drawn May 30, 1907. After six days evident thermal disturbances followed. The temperature again became normal twelve days after inoculation. Hogs Nos. 3 and 4 each received the same exposures, as follows: March 30, 1908, injected Sc. with 6 cc. of hog-cholera serum from hog No. 264, drawn May 30, 1907; April 10, fed viscera from hogs dead from cholera; May 1, fed hog-cholera blood and viscera from Riley outbreak; July 4, 1908, fed viscera and blood of hog-cholera hogs, Riley outbreak; July 25, placed in infected pen with sick hogs Nos. 9 and 10; August 18, injected Sc. with 5 cc. horse No. 3, 4-hour serum; September 28, fed hog-cholera viscera and placed in infected pen with hogs sick and dying from hog cholera.

Hog No. 7, white sow, weight on May 25 about 60 pounds: July 1, 1908, injected Iv. with 6 cc. hog-cholera serum, Riley outbreak. No immediate results appeared from inoculation. After several days, the animal gave evidence of a light chronic case of cholera, coughed some and showed some loss of flesh. July 6 this hog was again in normal condition. July 4, fed hog-cholera viscera and blood, Riley outbreak; July 25, placed in infected pen with sick hogs Nos. 9 and 10; August 18, injected Sc. with 5 cc. horse No. 3 4-hour serum; September 28, fed hog-cholera viscera, Norwood outbreak, and placed in infected pens with hogs sick and dying from the disease.

All of the hogs described above were immunized against the disease and are in excellent condition at the present time. (See half-tone, plate 14.)

The methods used in immunizing these hogs are unimportant in this connection. These animals, however, were immunized by the injection of hog-cholera virus, once highly virulent, but attenuated by age at the time of inoculation, and by exposure to the Riley strain of hog cholera, which was very chronic in character. The probable approximate date of acquiring immunity in each of these animals may be placed as follows:

Hog No. 1, during February, 1908.
Hog No. 2, during January, 1908.
Hog No. 3, during March, 1908.
Hog No. 4, during March, 1908.
Hog No. 7, during June, 1908.

These hogs have for the last three months been under conditions of intermittent exposure to hog cholera and are at present confined in pens infected with the acute type of the disease. In each case the duration of immunity has extended over the following periods:

Hog No. 1, approximate duration of immunity, seven months.
Hog No. 2, approximate duration of immunity, eight months.

Hog No. 3, approximate duration of immunity, six months.
Hog No. 4, approximate duration of immunity, six months.
Hog No. 7, approximate duration of immunity, three months.

VIII.

THE KEEPING QUALITIES OF HOG-CHOLERA VIRUS.

A limited amount of data has been obtained relative to the duration of virulence of hog-cholera serum. The observations which were made are as follows:

(a) Liquid Hog-cholera Serum.

On January 12, 1908, hog No. 2 was injected Sc. with 8 cc. of bay mare 6-hour serum. This 6-hour serum was drawn in April, 1907; on May 13, 1907, 10 cc. of this was injected subcutaneously into hog No. 264. Hog No. 264, after an incubation period of eight days, developed acute hog cholera and was moribund seventeen days after inoculation. Hog No. 2, which received 8 cc. of this virus, showed some disturbance in temperature and appetite five days after inoculation. These symptoms soon disappeared, however, showing the attenuated condition of the material. (See table 39.) Subsequent injections and exposures suggested that the attenuated virus served to immunize the animal against disease.

Hog No. 4, small white pig, weight about 40 pounds, on Februbary 29 received Sc. 2 cc. of virus from hog No. 259. Hog No. 259 had a severe case of the disease and was bled on May 16, 1907. Some reaction followed the injection of hog No. 3, but infection did not follow.

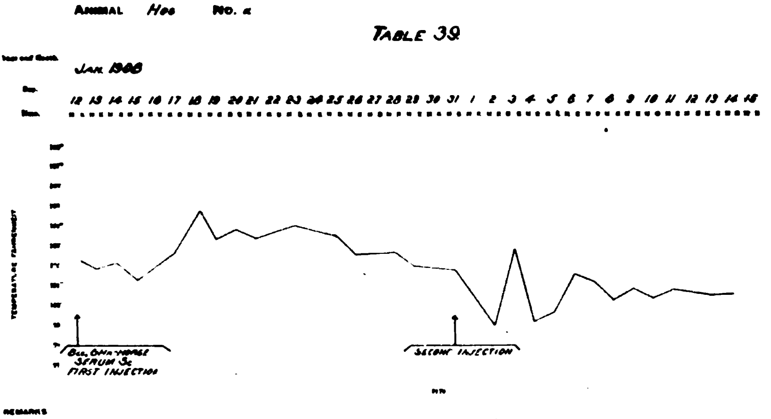


TABLE 39

(b) Dried Hog-cholera Serum.

Hog No. 2, on February 29, received 0.2 gm. of dried hog-cholera serum from hog No. 259, drawn May 16, 1907. This dried material was found to be virulent by the inoculation of a healthy hog. This was dried by exposure to a temperature of 37° C. No results followed this injection. The experiment is not conclusive, because of the fact that hog No. 2 had received previous inoculations of bay mare 6-hour serum, which had probably conferred immunity.

Hog No. 3, a small white pig, weighing about 35 pounds, on February 29 received 0.2 gm. of dried hog-cholera virus from hog No. 259, drawn May 16, 1907. No apparent reaction or evidences of infection followed this injection.

From the above experiments we find the following results:

(*a*) *Liquid Serum.*—Hog No. 2 was not infected by inoculation on July 12, 1908, with material which was obtained in April, 1907, and which produced the disease in a healthy pig in May, 1907; the virus had therefore lost its virulency after a period of nine months.

Hog No. 4 showed only a slight reaction when inoculated on February 29, 1908, with hog-cholera serum obtained from a severe case on May 16, 1907. Again after a period of nine months this virus had become attenuated.

(*b*) *Dried Serum.*—Hog No. 3 gave no evidence of disease after injection on February 29, 1908, with hog-cholera serum which was obtained on May 16, 1907, in a highly virulent condition, and was dried at a temperature of 37° C.

From the above limited amount of data (experiment with hog No. 3) the suggestion follows that neither hog-cholera virus nor a serum vaccine could be protected from deterioration by preserving it in a dry condition.

IX.

KEEPING QUALITIES OF HORSE-SERUM VACCINE.

The assumption could reasonably be made that horse-serum vaccine would probably retain its protective properties as long as does the virulent hog-cholera serum. The following recorded results, in so far as they extend, give some information on this point:

TABLE 37.

KEEPING QUALITIES OF HORSE-SERUM VACCINE.

Hog No.	Date of vaccination.	Character of vaccine used.	Result of vaccination.	Date vaccine was obtained.	Age of vaccine.
19	Sep. 2, 1908	30-hr. horse serum.	Successful.	Aug. 20, 1908	One week and six days.
21	Sep. 2, 1908	24-hr. horse serum.	Successful.	Aug. 24, 1908	One week and two days.
22	Sep. 2, 1908	24-hr. horse serum.	Successful.	Aug. 19, 1908	Two weeks.
18	Aug. 19, 1908	24-hr. horse serum.	Successful.	Jul. 18, 1908	Four weeks and four days.
23	Sep. 2, 1908	4-hr. horse serum.	Successful.	Jul. 17, 1908	Six weeks and four days.

The horse serum vaccines used in the inoculations indicated in table 37 were kept in a refrigerator, temperature approximately 12° C.

SUMMARY.

From the results which have thus far been obtained in the present work and from those of other investigators which have been reviewed in the preceding pages, the following conclusions seem warranted:

1. *Bacillus cholera suis* is not the etiological factor in all forms of hog cholera.
2. *Bacillus cholera suis* is possibly a variety of the common intestinal parasitic organism, *Bacillus coli communis*.
3. The specific cause of the "filterable virus form" of hog cholera appears to be some living organism, possibly ultramicroscopic, possibly capable of passing through a fine porcelain filter in some disintegrated state.
4. The filterable virus of hog cholera cannot be artificially cultivated in normal hog-serum broth in the abdominal cavity

of the rabbit in the collodium sac, according to the method used by Nocard and Roux in artificially cultivating the organism which they associate with contagious pleuropneumonia in cattle.

5. The simultaneous method of vaccination is efficient but is not practical because of its expense and the possible danger attending its use.

6. The ordinary laboratory and domesticated animals are not susceptible to the filterable virus of hog cholera.

7. Virulent hog-cholera serum exerts a toxic influence upon a healthy horse when injected intravenously.

8. Normal hog-cholera serum or virulent hog cholera serum does not appear to produce an anaphylactic reaction when injected intravenously into the horse.

9. The 2-hour horse serum (drawn from the horse two hours after the animal has received, intravenously, approximately 150 cc. of hog-cholera virus) when injected subcutaneously into the healthy hog in small quantities produces an acute form of the disease.

10. The 4-hour horse serum (blood serum from a horse drawn four hours after the animal has received intravenously approximately 150 cc. of virulent hog-cholera serum) when injected into healthy hogs intravenously produces acute hog cholera.

11. The 4-hour horse serum, under certain conditions at least, when injected subcutaneously in small doses into healthy swine does not produce infection.

12. The 5- to 7-hour horse serum when injected subcutaneously into the healthy hog does not produce the disease.

13. The 24-hour horse serum (drawn twenty-four hours after the animal has received intravenously approximately 150 cc. of hog-cholera serum), in comparison with 4-hour horse serum, shows attenuated properties.

14. The 24-hour horse-serum vaccine injected subcutaneously and intravenously, and 4-hour horse-serum vaccine when injected in small quantities subcutaneously, act as preventives against hog cholera. The 24-hour horse serum, however, is not constant in respect to its protective properties.

15. Acquired immunity against hog cholera extends over a period of from three to eight months.

16. A rough estimate shows that horse-serum vaccine can be prepared at a relatively low cost.

17. Virulent hog-cholera serum in the liquid form becomes attenuated after a period of nine months when kept at a temperature of approximately 10° C. to 15° C.

18. Virulent hog-cholera serum dried under aseptic conditions at a temperature of 37° C. becomes attenuated after a period of eight months.

19. Horse-serum vaccine retains its protective properties for at least a period of six weeks when kept at an approximate temperature of 10° C. to 15° C.

PROPOSED CONTINUATION OF PRESENT INVESTIGATION.

At the present time, active field-work with horse-serum vaccine in various parts of the state of Kansas is being undertaken. This work will be continued until the winter months, when the reports from the various field experiments will be secured and arranged in definite form.

At the Station, various experiments will be conducted with horse-serum vaccines drawn at different periods of time after the intravenous injection of the horse with the hog-cholera virus. As many series of hogs as opportunity will permit will be used under various conditions in testing the above vaccines.

Comparative leucocyte counts will be made of the blood of the horse before and after the intravenous injection of normal and hog-cholera serum.

Data will be obtained relative to the influence of one or more treatments of the horse with hog-cholera serum. This must be determined in order to be able to standardize correctly the horse-serum vaccine.

Continued observations will also be made upon duration of acquired immunity, possible immunity by inheritance, and the keeping qualities of hog-cholera virus and horse-serum vaccine.

Within the next few months it is expected that this bulletin will be followed by one which will review the present work in a more popular manner. The writer is aware of the fact that the contents of this bulletin consist of facts which are perhaps too technical to be of more than ordinary interest to the farmer, but it must be understood that in any investigation a certain amount of experimental and technical work must be accomplished before the final successful, practical product is obtained.

In the next bulletin the results of the field-work which is being conducted with the horse-serum vaccine will also be given.

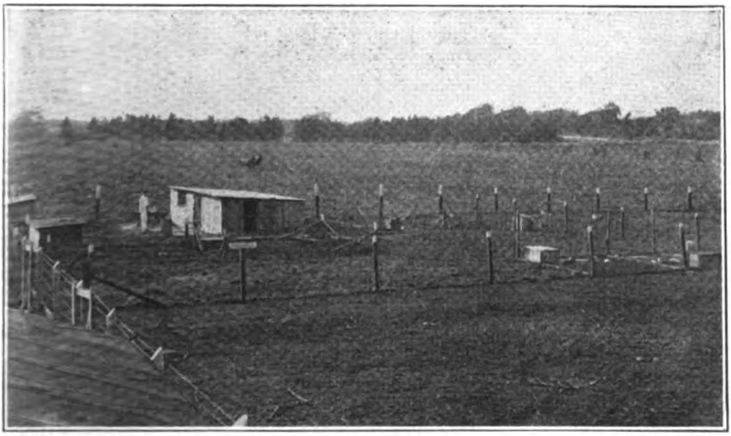


Plate 1. Hog yards for experimental hog-cholera work. Kansas Experiment Station.

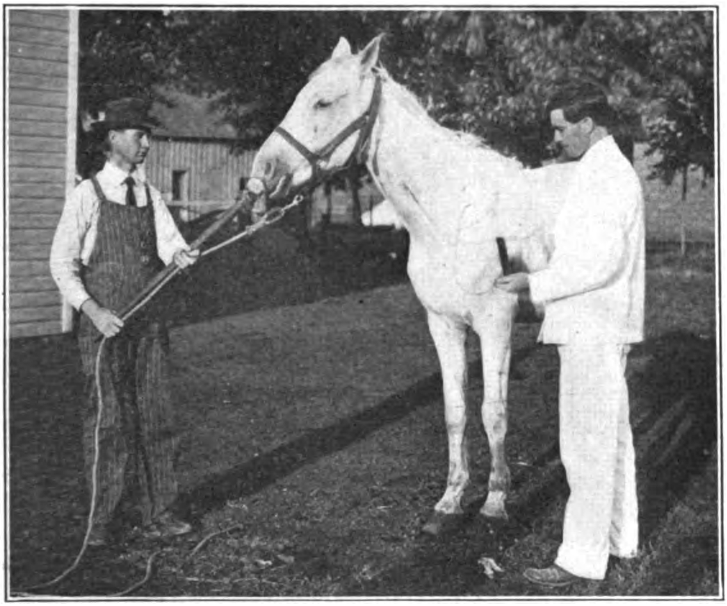


Plate 2. Intravenous injection of horse with hog-cholera virus.

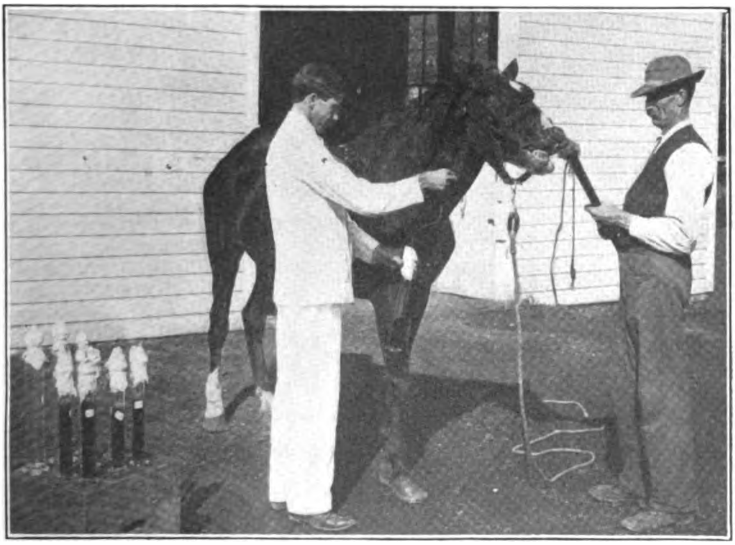


Plate 3. Bleeding the horse.

Plate 4. Spleen from original hog, Norwood, Kan., about twice the size of normal spleen of seventy-five-pound pig.

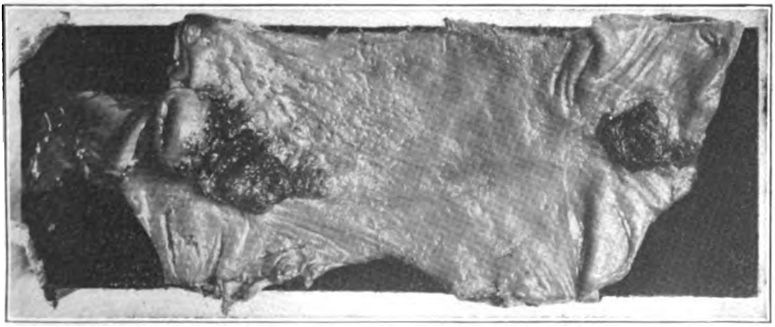


Plate 5. Ulcers in cæcum of original hog, Norwood, Kan.

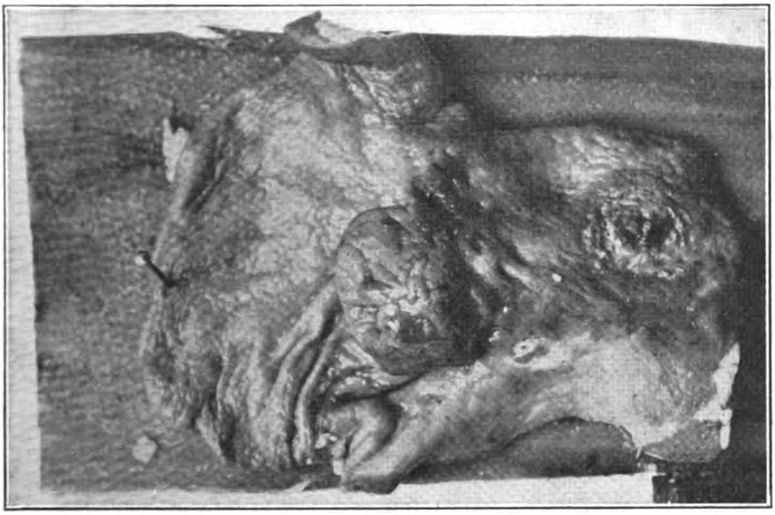


Plate 6. Ulcers in cæcum of hog No. 9.

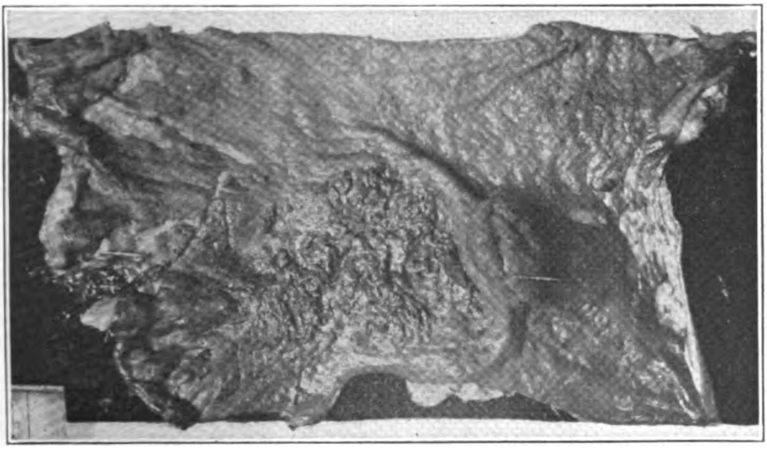


Plate 7. Ulcers in cæcum of hog No. 10.

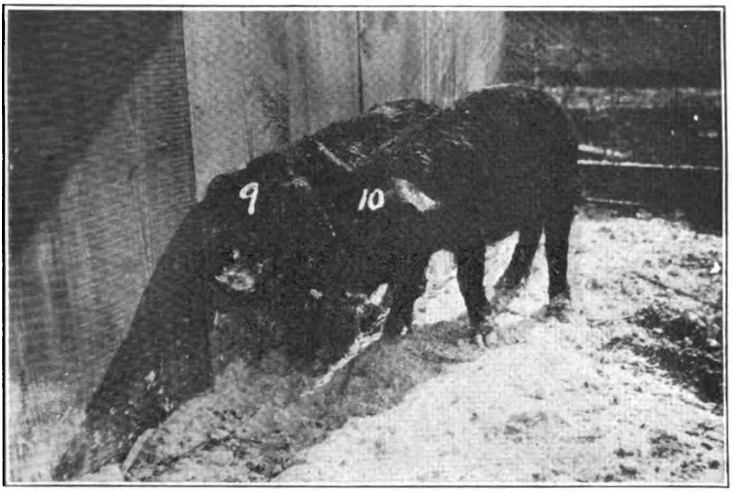


PLATE 8. Hogs Nos. 9 and 10, August 1, 1908, Fifteen days after inoculation.

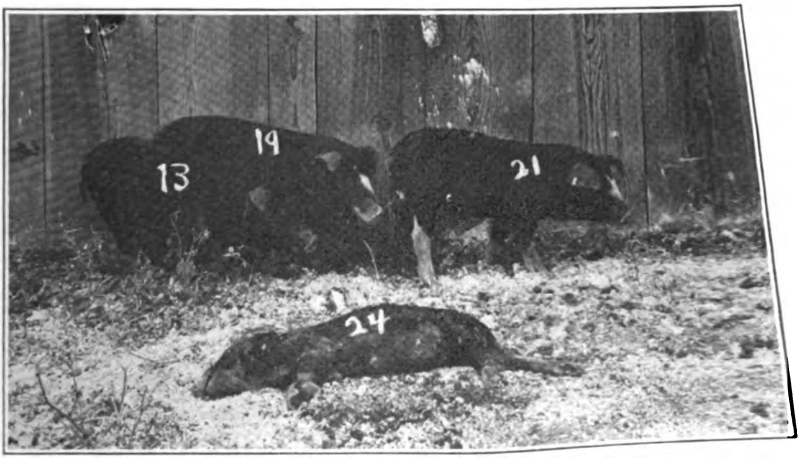


PLATE 9. Hogs Nos. 19, 13 and 21, and dead control, No. 24.

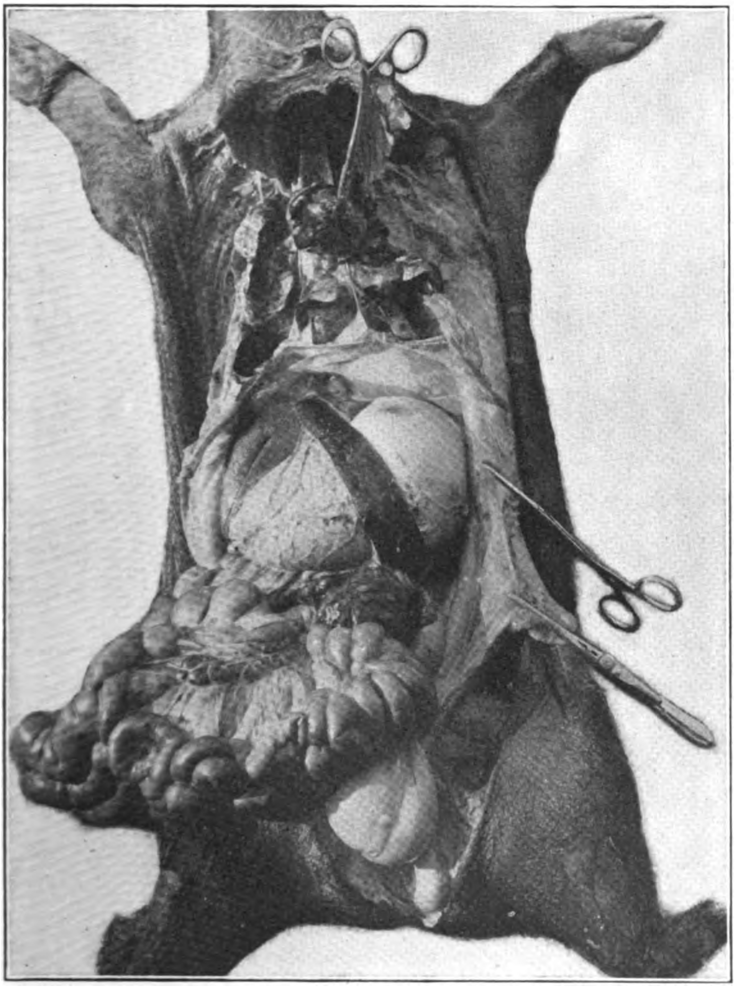


PLATE 10. Autopsy, hog No. 24, showing enlarged and hemorrhagic mesenteric glands, ulcerated cæcum, enlarged spleen, hemorrhagic areas on peritoneum, subcutaneous and muscular tissues, blood extravasations in heart muscle and hepatized and hemorrhagic portions of lungs.

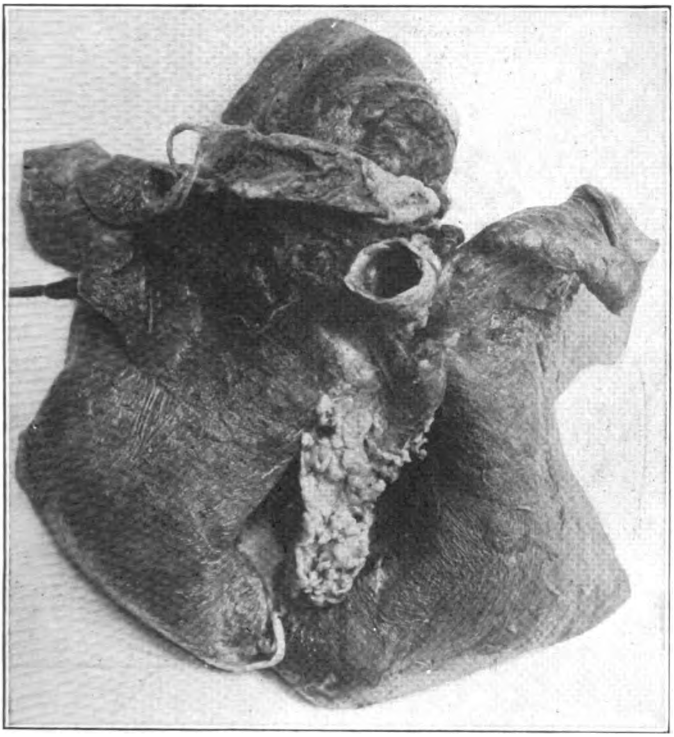


Plate 11. Heart and lungs, control hog No. 26, hepatized and hemorrhagic areas in both lungs, heart covered with blood extravasations and a fibrinous exudate.

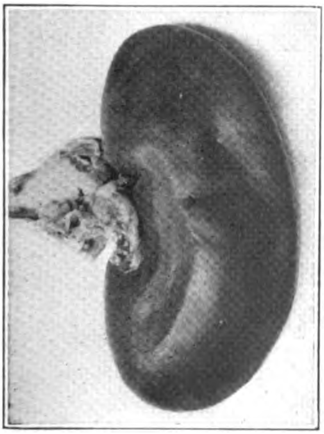


Plate 12. Kidney, control hog No. 26, showing petechiæ.

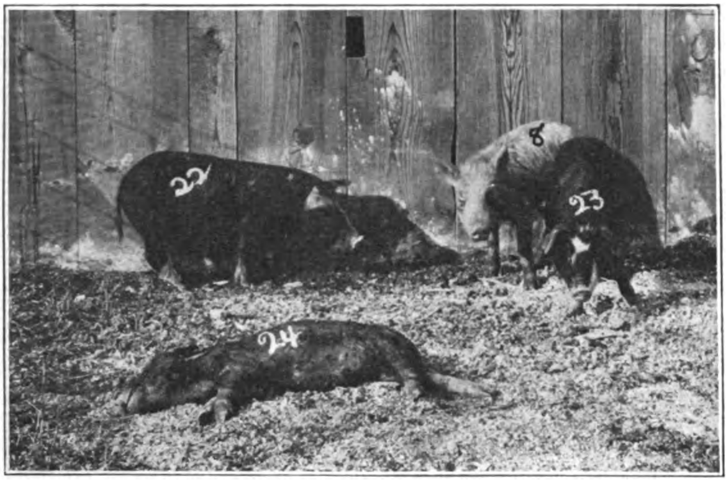


Plate 13. Hogs Nos. 22 and 23, with chronic case No. 8 and dead hog No. 24.

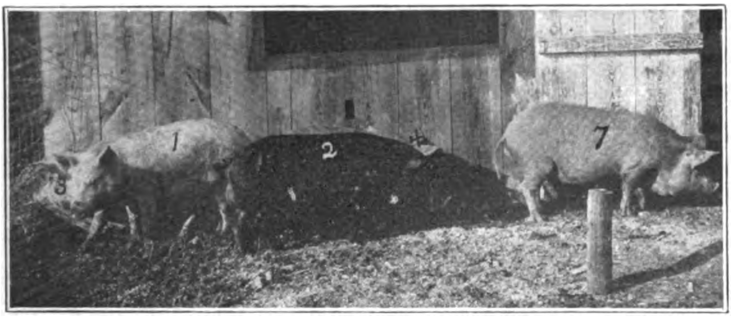


Plate 14. Immune hogs Nos. 1, 2, 3, 4 and 7—immunity having extended over a period of from three to eight months.

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The Bulletins of the Experiment Station are sent free to applicants. Farmers are invited to send the names of others who would value them and samples will be sent, with return cards upon which applications for future issues may be made.

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No. 158. March,'09.

Experiment Station.

Kansas State Agricultural College.

Bulletin No. 158—March, 1909.

Chemistry Department.

Analyses of Registered Feeding-stuffs.

MANHATTAN, KANSAS.
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Bulletin No. 158—March, 1909.

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W. E. MATHEWSON, M. S., Assistant Chemist.
C. O. SWANSON, M. Agr., Assistant Chemist.
E. L. SIEBER, A. M., Assistant Chemist.

Analyses of Registered Feeding-stuffs.*

THE Kansas law regulating the sale of concentrated feeding-stuffs, published as chapter 407 of the Laws of 1907, was printed in full in Bulletin No. 146. The law went into effect July 1, 1907. Many of the manufacturers concerned had not heard of the law and much correspondence for some months was necessary to acquaint them with its requirements and to secure registration of the feeding-stuffs sold by them. In view of the lack of knowledge concerning the law it seemed fairest not to begin at once a campaign of inspection, which would have amounted to little more than one of information. The chemical analyses of registered feeds made necessary in order to enable manufacturers to make a safe guaranty taxed the force of the department to such a degree that men could not have been spared well for inspection duties, hence inspection work was postponed until the latter part of the fall.

It developed early that in some quarters there had been a misunderstanding in respect to the scope and application of the law, although such a misunderstanding did not exist with members of the legislative committees of the senate and the house and the representatives of the milling interests present at the state capital when the law was under consideration. By these it was well recognized that the law was to apply to all ground feeds, including bran, shorts and corn chop. Indeed, much of the complaint showing the need of such a law had been with reference to those very feeds. Corn bran produced in the manufacture of corn-meal had been freely mixed with corn chop or wheat bran. Coarse screenings and other refuse obtained in preparing wheat for the rolls was worked off in the bran, and shorts often contained the dirt and other waste materials of a finer texture.

---

* In addition to those formally designated as assistants, several others have taken part in the analysis of feeding-stuffs. Among them are John W. Calvin, Adah Lewis, R. C. Thompson and H. C. McLean.

The opposition to the application of the law to these common mill feeds developed sufficient force, however, so that when the legislature was summoned in special session a bill was introduced designed to express the wishes of those who desired to exempt these feeds from its application. The director and the chemist of the Experiment Station, in conference with Representative Ham and others, coöperated in formulating amendments conceding the main point at issue, but providing that if these feeds and others made by grinding a single kind of grain be mixed with each other or other substances they shall come under full action of the law; and provision was also made for the inspection of all feeds on the market with reference to their purity, and also as to the correspondence of the actual net weight of packages with the weight as represented by the seller.

The original law had sought to levy an inspection tax of twenty-five cents per ton upon all concentrated feeding-stuffs in the state of Kansas. Being advised that such a provision was discriminatory and an interference with interstate commerce, and hence in all probability non-enforceable, the Station authorities early ceased all effort to collect that inspection tax. The special session gave an opportunity to correct this defect in the law and this was done. The inspection tax is, however, not collectible on all concentrated feeding-stuffs, but only on certain kinds named in the law. A tax to the extent of twenty-five cents per ton, to be paid by the purchase of tags, was provided for all such feeds sold or held for sale within the state of Kansas.

The law specifically provided that condimental feeds should conform to its requirements and that condimental or medicinal stock foods should pay a registration fee of fifty dollars for each brand selling for more than forty dollars per ton. This requirement naturally aroused the opposition of the manufacturers of this class of goods and they made strenuous efforts to evade the law, and the International Stock Food Company attempted by proceedings in the United States circuit court to secure a decision against the constitutionality of the entire law. The court decision, however, sustained the law in respect to the points at issue. The manufacturers of this class of substances have in some cases, by changing the names of their preparations, attempted to strengthen their cases in their opposition to conforming to the law. The Experiment Station authorities therefore took advantage of the opportunity afforded by the special session to have the law amended so as to include these substances under the various names by which they are designated.

In connection with this requirement for registration of condimental feeds it early became necessary to formulate a distinct idea in reference to them. The principle adopted was that articles other than ordinary feeds would be included in this category if they were advertised, sold or held for sale for the purpose of bringing about with animals any of the effects that are recognized as due to nutrition, such as increased growth, milk-production, egg-production, etc. It is true that purely medicinal substances by the correction of diseased conditions may indirectly produce such results. The class of substances under consideration are, however, further distinguished from medicines in that they are recommended for administration to animals in the ordinary condition of health, and usually daily or at regular intervals. Their use as advertised and recommended is not restricted or even adapted to the cure of disease, and since disease presents itself in so many forms it is obviously not in accordance with good judgment to use such preparations as medicines.

We have therefore required the registration fee to be paid upon all preparations for which the claims indicated are made, and will continue to require such payment regardless of the name under which the preparation is offered, and will not require the payment of the registration fee unless such claims are made. The following is given as a definition of such articles coming under the law: Condimental or medicinal stock foods and condimental feeds are held to be articles containing condimental or medicinal substances, or both condimental and medicinal substances, the product being recommended and sold for use with ordinary feeds of animals in the usual condition of health with the object of increasing the production of milk or eggs or increasing the growth or rate of fattening of animals, or of otherwise contributing to the nutrition of animals.

By registering these preparations under the circumstances detailed above, it must be distinctly understood that we in no way concede the truth of the claims made for them. Concerning their individual merits or the general advisability of using such articles we do not in this connection express any opinion.

As the changes in the law have vitally affected its scope it is printed herewith, introducing the amendments and amended sections as passed at the special session of 1908. It is as follows:

"AN ACT regulating the sale of concentrated feeding-stuffs, forbidding their adulteration, providing for their inspection and analysis, providing penalties for its violation, and repealing all acts or parts of acts in conflict with it.

"*Be it enacted by the Legislature of the State of Kansas:*

"SECTION 1. For the purposes of this act concentrated feeding-stuffs are declared to be all materials sold, offered for sale or held for sale within the state of Kansas and designed for the nutrition of animals of any species, if such materials have been subjected to any mixing process, or subjected to any process whereby the composition of the original material is altered. Condimental feeds, medicated stock foods, medicinal stock foods, stock food tonics, stock powders, condition powders, conditioners, animal regulators, proprietary feeds, or any preparations of like nature, are hereby expressly designated as coming under the provisions of this act, and all forms of animal life except man are included under the term 'animal.' The term 'brand' as used in this act is to be taken to mean, first, the name, trade-mark or other designation under which a concentrated feeding-stuff is sold, and, second, the feeding-stuff itself.

"SEC. 2. Every brand of concentrated feeding-stuff offered or held for sale within the state of Kansas shall be registered in the office of the director of the Agricultural Experiment Station of the Kansas State Agricultural College, and each sale of any concentrated feeding-stuff not so registered shall constitute a separate violation of this act. The manufacturer or seller of any concentrated feeding-stuff shall apply to the said director of the Experiment Station for registration and analysis of the feeding-stuff, and in his application for such registration and analysis he shall submit a statement of the several ingredients used in preparing the concentrated feeding-stuff and the sources from which they were obtained, which information shall be filed for reference, but shall not be disclosed by the said director if none of the ingredients are unwholesome, deleterious or fraudulent. If the feeding-stuff, as described by the manufacturer or seller, is found to consist of wholesome materials, and the name or brand used to designate it is not false or misleading, the said director of the Experiment Station shall register the name, brand or other designation of the concentrated feeding-stuff, its guaranteed composition in the terms stated in this section, and the name and address of the manufacturer or seller applying for the registration. Such registration shall be made annually, and the manufacturer or seller shall pay a registration fee of ten dollars for each brand of concentrated feeding-stuff registered; provided, that any manufacturer of condimental or medicinal stock foods shall pay a registration fee of fifty dollars for each brand selling for more than forty dollars per ton.

"SEC. 3. Whenever requested by the said director of the Experiment Station it shall be the duty of the manufacturer or seller who secured registration of a brand of concentrated feeding-stuff to furnish said director a true and complete list of the names and places of business of all dealers in said brand of concentrated feeding-stuff who purchased it of the said manufacturer or seller and reside within the state of Kansas. Failure to furnish such list shall be sufficient ground for revocation of the registration of said concentrated feeding-stuff.

"SEC. 4. Every sack, box, carton or other package of concentrated feeding-stuff offered or held for sale or sold within the state of Kansas shall bear a distinctly printed and conspicuous label in the English language, which shall state the name and address of the manufacturer or seller, the registered name, trade-mark or other designation of the concentrated feeding-stuff, the net weight of the package, and the guaranteed percentage of fat and of protein.

"SEC. 5. An inspection tax shall be collected upon all cottonseed-meal, cottonseed-cake, linseed-oil meal, linseed-oil cake and feeding-stuff by-products of starch factories, glucose factories, cereal breakfast-food factories, breweries and distilleries, meat-packing establishments or slaughtering-houses, that are sold, offered for sale or held for sale within the state of Kansas, which tax shall be at the rate of twenty-five cents per ton, except as hereinafter stated. Every sack, box, carton or other package of the feeding-stuffs named in this section that is sold, offered for sale, held for sale or in the possession of any one within the state of Kansas shall bear at least one tag certifying that the tax aforesaid has been paid on one hundred pounds or a fraction thereof. If any package contains more than one hundred pounds it shall bear one tag for each one hundred pounds or fraction thereof, and in case the concentrated feeding-stuff is sold in bulk, one tag shall be delivered with each one hundred pounds or fraction thereof. All tags required under the provisions of this section shall be obtained from the aforesaid director of the Experiment Station in lots of four hundred or multiples thereof, and he shall receive from the manufacturer or seller five dollars for each four hundred so furnished. Such tags shall be good until used, but counterfeiting them or using them more than once is prohibited. The tax so collected, together with all registration fees collected, shall be used, so far as may be necessary, in defraying the expenses of inspection and analysis of concentrated feeding-stuffs, as hereinafter provided, and if any residue remains it shall be turned into the general funds of the Experiment Station aforesaid; provided, however, that employees of the state upon salaries shall not receive any additional compensation for making such inspection and analysis.

"SEC. 6. In so far as the revenues provided by this act or otherwise may suffice, it shall be the duty of the chemist of the Experiment Station aforesaid to make, or cause to be made, such inspection and analysis of concentrated feeding-stuffs as in his judgment may be deemed necessary to ascertain whether or not manufacturers and others are complying with all the provisions of this act. Toward this end he or his authorized deputies shall procure annually at least one sample of each brand of concentrated feeding-stuff registered for sale within the state of Kansas, and shall make, or cause to be made, an analysis of the same, according to the methods of the Association of Official Agricultural Chemists, and a certified statement of the results of such analysis shall be *prima facie* evidence in any legal action within the state of Kansas concerning such concentrated feeding-stuff; provided, however, that employees of the state upon salaries shall not receive any additional compensation for making such inspection or analysis.

"SEC. 7. In sampling concentrated feeding-stuffs in lots of ten or less packages, portions shall be taken from each package; in lots of more than ten packages and not more than five tons, samples shall be taken from not less than ten packages and from not less than ten per cent. of the packages. In lots of over five tons portions shall be taken from not less than twenty packages. In sampling concentrated feeding-stuffs in bulk, not less than ten portions shall be drawn, and these from various parts, so as to represent fairly the whole. The portions drawn shall be carefully mixed and from the mixture two samples of about two pounds each reserved and placed in sealed bottles or jars, and accurately labeled. One of these samples shall be delivered to the owner of the concentrated feeding-stuff, or his representative, the other taken for the use of the chemist of the Experiment Station. Sampling shall be during ordinary business hours, and the owner of the concentrated feeding-stuff, or his representative, may be present, but any refusal by such owner or his representative to permit sampling shall be taken as sufficient evidence of violation of this law by him.

"SEC. 8. Any manufacturer, seller or holder of concentrated feeding-stuffs who shall fail to comply with all the provisions of this act, or who shall sell, offer for sale or hold for sale any concentrated feeding-stuffs the composition of which is not in accordance with that guaranteed, upon conviction shall be deemed guilty of a misdemeanor and fined not less than fifty dollars nor more than two hundred dollars and costs for the first offense, and not less than one hundred dollars nor more than five hundred dollars and costs for each subsequent offense; provided, that any seller shall be exempt from the penalty for sale of concentrated feeding-stuffs that are below the guaranteed standard if he has a written guaranty from the manufacturer or seller of the concentrated feeding-stuff that said feeding-stuff is registered and of the guaranteed composition, if said manufacturer or seller is a resident of the state of Kansas. Suit may be brought for the recovery of penalties under the provisions of this act in the district court of the county where the offense is alleged to have been committed, and shall be prosecuted by the county attorney in the name of the state of Kansas, upon complaint of the said director of the Experiment Station or of some reputable citizen of the county. Each sale shall constitute a separate offense. Penalties recovered under this act shall be turned into the school fund of the county wherein the offense was committed. In cases involving the composition of the concentrated feeding-stuff a deficiency not greater than one-fifteenth of the guaranteed percentage of any ingredient shall not be taken as evidence of fraudulent intent, but the seller of any concentrated feeding-stuff that does not possess the composition guaranteed shall be liable for damages resulting to the user in consequence thereof.

"SEC. 9. The Experiment Station aforesaid shall publish at least annually a bulletin giving a list of the concentrated feeding-stuffs registered for sale in this state, with their guaranteed composition and such other information as may be deemed valuable to the public concerning them and their use. This bulletin shall also contain a list of the manufacturers and sellers of concentrated feeding-stuffs in this state, according to the statements secured under the provisions of section 3.

"SEC. 10. The adulteration of any concentrated feeding-stuff by the addition of foreign mineral matter, or by the addition of foreign animal or vegetable matter of little or no nutritive value, and the use or addition of substances poisonous or deleterious to animals, is forbidden. This section shall not be so construed as to prevent the compounding and sale of balanced feeds or condiments, the composition of which has been duly declared and approved in accordance with the provisions of section 2.

"SEC. 11. The provisions of this act shall not apply to goods sold by one manufacturer to another; nor to feed ground or mixed by the consumer of the same; nor to wheat bran, wheat shorts, wheat middlings, wheat screenings, rye bran, rye shorts, rye middlings, buckwheat bran, corn bran, corn-meal, corn chop, corn-and-cob meal, ground Kafir-corn, ground sorghum seed, ground broom-corn seed, ground milo maize, ground emmer, ground speltz, ground rye, ground barley, or sugar-beet pulp, when the same is not mixed with other grains, or with other substances, or with each other; but the feeding-stuffs named in this section shall be subject to the inspection provided for in section 6, for the purpose of ascertaining whether or not they are in fact sold, held for sale or offered for sale in the pure state, and in packages the weight of which, on the average, is equal to that which it is represented to be.

"SEC. 12. All acts and parts of acts in conflict with this act are hereby repealed.

"SEC. 13. This act shall go into effect on the first day of July, 1907, after its publication in the statute-book.

"Original act approved March 5, 1907. Published May 27, 1907.

"Amendments approved January 31, 1908. Published February 5, 1908."

After the revised law was in effect inspection work was resumed, and the principal towns of the greater part of the state where the sale of concentrated feeding-stuffs is an important business were visited. As bran, shorts and corn chop were no longer under the law, samples were not collected of these feeds, even though previously registered, excepting as such collection was deemed advisable on account of suspected adulteration. The first work of inspectors must necessarily be largely one of education, and by friendly means to induce manufacturers and dealers to comply with the law. We have no desire to institute legal proceedings, and it is a pleasure to state that in most cases manufacturers and dealers are willing to comply with the law, and regard it as a good one for all concerned. The accompanying table shows the composition of certain registered feeds in respect to protein and fat, guaranty under which they were offered by the manufacturers, and the results obtained on analysis of the inspection sample or samples. In considering these results it must be borne in mind that the original samples as sent for analysis were not taken by those skilled in such work and acquainted with the importance of observing minute details of care in order to obtain a fairly representative sample. It must also be recognized that the moisture content of feeds is subject to a certain variation. All samples taken by the inspectors for analysis were placed in sealed glass jars and changed little afterward. The samples first sent in by the manufacturers may have undergone alteration due to atmospheric conditions. Further, it must be borne in mind that the raw materials upon which the manufacturer operates must necessarily vary to a greater or less extent. It is the duty of manufacturers to take this into account in making their guaranty. To avoid doing injustice to a well-intentioned dealer or manufacturer the law itself further provides that a deficiency not greater than one-fifteenth of the guaranteed percentage of any ingredient shall not be taken as evidence of fraudulent intent.

RESULTS OF ANALYSES OF REGISTERED FEEDS SAMPLED PREVIOUS TO JULY 1, 1908.

Inspection No.	Registration No.	KIND OF FEED.	Manufacturer.	Composition of sample furnished.		Composition guaranteed by manufacturer.		Composition of inspection sample.	
				Protein.	Fat.	Protein.	Fat.	Protein.	Fat.
1	588	Corn Chop	**Alfred Weston, Kansas City, Mo.**	8.40	4.02	8.40	4.02	8.80	4.01
2	566	do.	Joe Stahl, Kansas City, Mo.	9.33	3.98	8.00	3.30	8.25	4.51
3	440	do.	Blacker Grain Co., Kansas City, Mo.	8.21	4.24	8.21	4.24	8.45	4.17
4	512	Bran	Solomon Valley Milling Co., Osborne, Kan.	16.17	3.91	16.17	3.91	17.25	3.68
5	395	Shorts	Hogan Milling Co., Junction City, Kan.	14.87	3.85	14.87	3.85	18.85	4.68
6	394	Bran	do. do. do.	13.98	4.41	13.98	4.41	15.63	4.36
7	......	Corn Chop	**Chas. Stevens, Junction City, Kan.**	....	....	....	....	9.60	3.77
8	502	Bran	**Aurora Mills,** do.	16.49	4.61	16.49	4.61	16.26	4.35
9	504	Corn Chop	do. do.	9.04	3.86	9.04	3.86	8.78	3.54
10	503	Shorts	do. do.	17.47	4.84	17.47	4.84	16.23	4.02
11	786	Corn Chop	**O. P. Fenton, Abilene, Kan.**	9.70	4.05	8.49	3.88	10.50	3.97
12	282	Shorts	**Abilene Milling Co., Abilene, Kan.**	16.77	4.35	15.50	4.25	18.25	4.08
13	281	Bran	do. do. do.	16.00	4.07	14.50	4.05	15.53	3.82
14	283	Corn Chop	do. do. do.	9.81	4.39	9.00	4.15	11.23	3.53
15	903	do.	J. H. Gentry, Minneapolis, Kan.	9.98	4.20	....	....	9.98	4.20
16	134	do.	Farmers' Elevator Co., Minneapolis, **Kan.**	8.95	4.12	8.75	4.00	9.00	2.66
17	679	do.	John Hartley, Minneapolis, Kan.	8.93	3.95	....	....	8.93	3.95
18	904	Shorts	Minneapolis Mill and Elevator Co., **Minneapolis, Kan.**	17.04	3.57	17.04	3.57	18.00	3.63
19	892	Bran	do. do. **do.**	16.50	3.35	16.50	3.75	17.65	3.62
20	905	Corn Chop	do. do. **do.**	9.61	3.70	9.61	3.70	10.65	3.78
21	85	Middlings	**Jackman Roller Mills, Minneapolis, Kan.**	16.64	4.59	16.50	4.50	20.47	4.78
22	84	Bran	do. do. do.	14.28	4.46	14.25	4.40	17.10	3.62
23	28	do.	**Hoffman Milling Co., Enterprise, Kan.**	14.38	4.02	14.20	4.00	17.45	3.78
24	29	Shorts	do. do. do.	16.73	4.77	16.65	4.75	19.55	4.58
25	354	Armour's Helmet Brand Meat Meal	**Armour Packing Co., Kansas City, Kan.**	62.48	12.89	60.00	12.00	61.40	13.71
26	695	Armour's Helmet Brand Blood Meal	do. do. do.	87.88	0.23	87.00	2.50	92.70	0.19
27	694	Armour's Helmet Brand Ground Bone	do. do. do.	25.26	0.80	25.00	5.00	26.00	1.00
28	22	Wheat Middlings	**Lee-Warren Milling Co., Salina, Kan.**	16.56	4.56	16.18	3.40	20.75	4.47
29	683	Corn Chop	**John Finley, Salina, Kan.**	9.18	4.62	....	....	9.90	3.86
30	682	Mixed Feed	do. do.	12.69	4.23	....	....	16.35	4.08
31	25	Wheat Middlings	**The Western Star Milling Co., Salina, Kan.**	17.24	4.74	16.18	3.50	21.10	4.40
32	26	Corn Chop	do. do. do.	8.52	3.82	7.90	3.40	11.37	3.88
33	24	Bran	do. do. do.	16.07	4.06	14.17	3.50	18.40	4.03
34	123	Corn Chop	**Ed Lotz, Salina, Kan.**	8.91	4.44	8.50	4.25	11.47	3.58
35	123	do.	do. do.	....	....	9.00	4.25	11.80	3.91
36	275	Mixed Feed	do. do.	12.03	4.42	12.00	4.25	16.57	4.37
37	10	Wheat Middlings	**Shellabarger Mill and Elevator Co., Salina, Kan.**	17.75	4.60	15.75	4.00	21.05	4.54
38	......	Cracked Corn	do. do. do.	....	....	10.50	3.90	11.05	3.23

39	11	Mixed Feed	Shellabarger Mill and Elevator Co., Salina, Kan.	14.05	4.30	14.00	4.25	14.90	4.12
40	21	Wheat Bran	Lee-Warren Milling Co., Salina, Kan.	14.49	3.96	14.17	3.50	17.65	3.61
41	9	Bran	Shellabarger Mill and Elevator Co., Salina, Kan.	16.70	4.26	14.00	3.50	17.57	3.82
42	54	Corn Chop	Smoky Valley Roller Mills, Lindsborg, Kan.	....	....	9.81	4.45	10.96	3.54
43	52	Wheat Bran	do. do. do.	....	....	13.00	3.50	18.15	3.61
44	53	Pure Wheat Shorts	do. do. do.	....	....	16.00	4.00	20.00	4.62
45	90	Pure Wheat Bran	Lindsborg Mill and Elevator Co., Lindsborg, Kan.	14.81	4.35	13.00	4.00	17.25	3.78
46	91	Pure Wheat Shorts	do. do. do.	17.13	4.94	16.00	4.00	17.10	3.96
47	764	Wheat Bran	H. E. Peck Roller Milling Co., Bridgeport, Kan.	....	....	18.58	3.90	18.70	3.66
48	763	Wheat Shorts	do. do. do.	....	....	19.08	3.84	19.55	3.59
49	665	Pure Wheat Shorts	The New Pearl Milling Co., McPherson, Kan.	17.06	4.85	16.00	4.25	16.40	4.08
50	666	Bran	do. do. do.	15.47	4.33	14.85	3.80	15.80	4.29
51	32	Corn Chop	Colburn Bros., McPherson, Kan.	9.74	4.51	9.00	4.00	10.10	4.12
52	30	Pure Winter-wheat Bran	do. do.	14.63	4.41	14.00	3.50	19.15	4.23
53	31	Wheat Shorts	do. do.	16.33	5.16	16.00	4.00	18.75	4.47
54	106	Pure Wheat Bran	Wall-Rogalsky Mlg. Co., McPherson, Kan.	15.08	4.54	14.00	3.50	16.85	3.48
55	444	Pure Corn Chop	do. do. do.	9.25	3.67	10.03	5.00	10.55	3.53
56	407	Pure Wheat Shorts	do. do. do.	16.56	5.04	16.00	4.50	18.85	4.72
57	34	Bran	Lyons Milling Co., Lyons, Kan.	15.67	4.32	15.50	4.25	18.35	4.31
58	35	Shorts	do. do.	17.78	5.52	17.75	5.50	20.25	4.17
59	36	Corn Chop	do. do.	9.35	4.08	9.35	4.05	10.65	3.40
60	314	Mill Run	Central Kansas Milling Co., Lyons, Kan.	15.81	4.81	15.00	4.00	17.80	4.12
61	318	Bran	do. do. do.	15.77	4.38	15.00	4.00	17.95	4.20
62	317	White Shorts	do. do. do.	....	3.78	16.00	4.00	18.00	3.90
63	589	Corn Chop	do. do. do.	10.16	3.85	....	....	8.50	3.45
64	537	do.	L. Lee, Larned, Kan.	9.68	4.31	9.41	4.08	10.45	4.01
65	950	do.	Albert Anderson, Larned, Kan.	7.98	2.47	8.50	3.85	9.85	3.89
66	853	do.	Grant Milling Co., do.	10.32	3.98	9.96	3.85	9.65	3.28
67	851	Bran	do. do.	17.87	3.39	16.00	3.33	18.25	3.39
68	852	Shorts	do. do.	15.67	4.24	15.00	4.00	20.10	4.04
69	644	Bran	Keystone Milling Co., Larned, Kan.	....	....	16.25	3.30	18.85	3.70
70	643	Corn Chop	do. do.	....	....	10.00	4.10	9.13	3.47
71	642	Shorts	do. do.	....	....	....	....	18.75	3.42
72	641	Mixed Feed	do. do.	....	....	17.50	3.20	18.55	3.58
73	604	Low Grade Flour	Ellinwood Mill and Elevator Co., Ellinwood, Kan	15.50	2.28	15.50	2.28	15.70	1.96
74	518	Pure Corn Chop	do. do. do.	9.44	3.98	16.24	4.17	16.20	3.59
75	518	do. do.	do. do. do.	....	....	9.00	4.00	9.96	3.45
76	520	Pure Wheat Middlings	do. do. do.	17.38	4.86	17.38	4.86	19.10	4.48
77	338	Mixed Feed	Moses Bros. Mill and Elevator Co., Great Bend, Kan.	17.16	4.12	17.00	4.04	18.61	3.61
78	380	Wheat Bran	do. do. do.	15.18	4.39	15.08	4.24	18.15	3.36
79	382	White Shorts	do. do. do.	17.27	3.71	17.04	3.64	19.60	3.74
80	331	Wheat Shorts	do. do. do.	16.60	4.06	16.44	4.00	18.87	4.06
81	415	Corn Chop	do. do. do.	9.25	4.41	9.19	4.34	9.75	3.17
82	367	Pure Corn Chop	Barton Co. Flour Mills, Great Bend, Kan.	9.53	4.02	9.00	4.00	10.45	3.58
83	363	Pure Wheat Bran	do. do. do.	15.28	4.18	15.00	4.00	18.05	3.50
84	365	Pure Wheat White Shorts	do. do. do.	16.91	4.06	16.00	4.00	20.75	3.86
85	364	Pure Wheat Brown Shorts	do. do. do.	17.63	4.44	17 00	4.00	20.60	4.59
86	366	Pure Wheat Mixed Feed	do. do. do.	16.61	4.14	16.00	4.00	19.62	3.96
87	202	Shorts	Walnut Creek Milling Co., Great Bend, Kan.	18.11	4.85	16.94	4.63	21.05	5.00
88	201	Bran	do. do. do.	14.98	4.01	13.81	3.30	18.10	3.61

RESULTS OF ANALYSES—CONCLUDED.

Inspection No.	Registration No.	KIND OF FEED.	Manufacturer.	Composition of sample furnished.		Composition guaranteed by manufacturer.		Composition of inspection sample.	
				Protein.	Fat.	Protein.	Fat.	Protein.	Fat.
89	204	**Corn Chop**	**Walnut Creek Milling Co., Great Bend, Kan.**	8.93	3.64	8.50	3.25	9.15	3.88
90	1017	**Chick Feed**	Pinkerton Mfg. Co., Lincoln, Neb.	11.58	1.96			11.90	1.48
91	1029	**Old Gold Brand Cotton Seed Meal**	T. H. Bunch, Little Rock, Ark.			41.00	9.00	42.03	7.85
92	1029	**Old Gold Brand Cotton Seed Meal**	do. do.			41.00	9.00	44.03	8.56
93	454	**Tankage**	Swift & Co., St. Joseph, Mo.			60.10	10.00	56.30	10.25
94		**Meat Meal**	do. do.			46.00		54.89	12.15
95									
96	423	Linseed Meal	Kansas City Lead and Oil Works, Kansas City, Mo.	34.66	7.19			33.30	9.22
97	876	Alfalfa Meal	Topeka Alfalfa Mfg. Co., Topeka, Kan.	15.55	1.65	15.55	1.65	17.14	1.72
98	354	Meat Meal	Armour Packing Co., Kansas City, Kan.	62.48	12.89			60.20	14.75
99		Meat Meal and Ground Bone	do. do. do.					58.72	12.06
100	694	Ground Bone	do. do. do.	25.26	0.80			26.03	1.60
101	442	Purina Chick Feed	Ralston Purina Co., St. Louis, Mo.	11.66	3.97	12.00	3.00	11.14	3.24
102	820	Cotton Seed Meal	W. H. Coyle Co., Guthrie, Okla.					43.20	7.43
103		Alfalfa Stock Food	Otto Weiss Stock Food Co., Wichita, Kan.	12.50	3.73	13.29	4.37	11.51	2.96
104	606	Linseed Oil Meal	Hess & Small, Fredonia, Kan.	31.93	14.12	31.93	8.00	33.28	8.88
105	695	Blood Meal	Armour Packing Co., Kansas City, Kan.	87.83	0.28			90.40	0.05
106	423	**Linseed Meal**	Kansas City Lead and Oil Works, Kansas City, Mo.	34.66	7.19	32.34	6.00	35.18	6.76
107	614	**Mixed Feed**	Lord Milling Co., Wamego, Kan.	15.68	5.88	14.00	3.50	14.51	3.78
108	703	**Owl Cotton Seed Meal**	F. W. Brode Co., Memphis, Tenn.			41-43	7-9	41.68	7.40
109	826	**June Pasture**	H. C. Peters Mill Co., Omaha, Neb.	10.70	1.56			12.20	0.49
110	808	**Alfalfa Meal**	Newton Alfalfa Mills, Newton, Kan.	16.47	2.20	15.00	2.20	16.04	2.63
111	993	**Mixed Feed**	Oswego Seed & Grain Co., Oswego, Kan.	11.85	3.59	15.08	3.13	13.81	2.59
112	4	**Chick Feed**	Otto Weiss Stock Food Co., Wichita, Kan.	11.02	2.76	11.02	2.76	10.14	0.51
113	355	**Mixed Feed**	Pearl Roller Mills, Oswego, Kan.	14.08	4.77	12.14	1.64	17.89	2.79
114	699	**Bran and Chop**	T. A. Beck, Topeka, Kan.	13.63	4.24	13.63	4.24	12.79	2.98
115	760	**Mixed Chop**	D. O. Coe, Topeka, Kan.	9.51	3.84	9.51	3.84	9.66	2.48
116		**Sterling Chick Feed**	Great Western Cereal Co., Chicago, Ill.			12.00	3.50	10.69	2.28
117	1019	**Chick Feed**	T. A. Beck, Topeka, Kan.	10.25	3.36			9.49	2.10
118	698	**Mixed Chop**	do. do.	9.27	4.29	9.27	4.29	9.59	2.89
119	992	**Chick-O**	D. O. Coe, Topeka, Kan.	11.79	4.14	11.79	4.14	10.89	2.92
120	340	**Purity Baby Chick Feed**	Zimmerman Seed Co., Topeka, Kan.	9.08	3.27	9.08	3.27	9.59	2.89
121	761	**Mixed Feed**	D. O. Coe, Topeka, Kan.	12.78	4.04			12.11	2.98
122	988	**Meat Meal**	Chas. Wolff Packing Co., Topeka, Kan.	58.08	17.64	60.00		58.77	12.20
123	808	**Alfalfa Meal**	Newton Alfalfa Mills, Newton, Kan.	16.47	2.20	15.00	2.20	16.79	1.78
124	707	**Mixed Chop**	J. B. Billard, North Topeka, Kan.	9.41	4.42	9.15	4.15	10.74	1.27
125	708	**Bran and Chop**	do. do.	12.58	4.15	12.25	3.90	11.98	3.72
126	792	**Mixed Chop**	Forbes Bros., North Topeka, Kan.	9.08	4.15	9.08	4.15	9.74	3.21

127	749	Corn and Oat Chop	H. Eichenlaub, Seneca, Kan.	10.00	4.12	10.00	4.12	9.21	2.85
128	1026	Linseed Meal	Midland Linseed Co., Minneapolis, Minn.	33.48	6.95	....	....	34.88	7.57
129	......	Linseed Oil Meal	do. do.	....	....	30-35	5.5-8.5	34.96	7.82
130	762	Superior Mixed Chicken Feed	D. O. Coe, Topeka, Kan.	10.24	3.19	10.24	3.19	9.46	0.56
131	......	Ideal Horse and Mule Feed	Atchison Oatmeal & Cereal Co., Atchison, Kan.	....	....	7.85	2.78	8.49	1.45
132	100	Oat Nutriment	do. do. do.	19.25	3.80	18-19.25	7-8.3	17.29	6.96
133	825	Arab Horse Feed	M. C. Peters Milling Co., Omaha, Neb.	10.91	3.95	11,00	3.00	10.46	2.90
134	456	Beef Scraps	Swift & Co., Kansas City, Kan.	....	....	60.00	8.00	58.17	7.52
135	1014	Alfalmo Fat	Alfalfa Meal Co., Council Bluffs, Iowa	10.67	0.35	18.00	2.00	10.90	0.37
136	302	Wheat and Corn Bran	Blaker Mfg. Co., Pleasanton, Kan.	13.45	5.40	....	....	14.00	3.37
137	......	Balanced Stock Food	Kansas Milling Co., Wichita, Kan.	....	....	41.00	7.00	40.40	8.89
138	......	Choice Cotton Seed Meal	Coate Bros., Memphis, Tenn.	....	....	41.00	7.00	39.80	8.61
139	1044	Cold Pressed Cotton Seed Cake	Frio Cotton Oil Co., Pearsall, Tex.	....	....	24.80	7.00	31.00	8.21

ANALYSES OF REGISTRATION SAMPLES.

Probably no such extensive examination of bran, shorts and corn chop in respect to protein and fat has been made previously as that involved in the analyses made in this laboratory the past year under the provisions of the law. Because of this, and from the general interest in comparing results, the accompanying tables are given, which show all the results obtained on samples of feeding-stuffs registered within the fiscal year. As condimental feeds are not administered for their content of protein and fat, and manufacturers do not care to make a guaranty on those points, as a rule these have not been analyzed.

The order of arrangement of the feeds in the table is alphabetical in respect to place of business of the person or firm making the registration.

ANALYSES OF REGISTERED FEEDS, ARRANGED ALPHABETICALLY BY STATES, POST-OFFICES AND MANUFACTURERS.

ADDRESS.	Manufacturer.	Registration No.	Feed.	Per cent. protein	Per cent. fat
Little Rock, Ark.	T. H. Bunch Co.	1029	"Old Gold" Cottonseed Meal		
do.	Consumers Cotton Oil Co.	887	Cottonseed Meal	44.22	8.10
Denver, Colo.	Ady & Crowe Mercantile Co.	1006	A. & C. Alfalfa Molasses Feed	12.30	0.47
Chicago, Ill.	Swift & Co.	454	Swift's Digester Tankage		
do.	do.	455	Swift's Blood Meal		
do.	do.	456	Swift's Beef Scraps		
do.	do.	457	Swift's Poultry Bone		
East St. Louis, Ill.	Corno Mills Co.	998	Corno Hen Feed		
do.	do.	999	Corno Chick Feed		
Freeport, Ill.	The W. T. Rawleigh Medical Co.	344	Stock Food	14.81	5.58
Quincy, Ill.	T. H. Jackson & Co.	1081	Commonsense Renovating Powders		
Waukegan, Ill.	J. W. Barwell	898	Blatchford's Calf Meal		
Chickasha, I. T.	Chickasha Cotton Oil Co.	715	"Feeder" Cottonseed Meal		
do.	do. do.	716	"Good" Cottonseed Meal		
do.	do. do.	717	"Prime" Cottonseed Meal		
do.	do. do.	718	"Choice" Cottonseed Meal		
Duncan, I. T.	Duncan Cotton Oil Co.	742	"Good" Cottonseed Meal		
do.	do. do.	743	"Prime" Cottonseed Meal		
do.	do. do.	744	"Choice" Cottonseed Meal		
Burlington, Iowa.	A. F. Miller Chemical Works	850	Dr. Miller's Lucky Strike Stock Tonic	28.55	6.25
Keokuk, Iowa	S. F. Baker & Co.	988	Baker's Condition Powders	14.47	8.88
do.	K. K. K. Medicine Co.	873	K. K. K. Condition Powders		
Shenandoah, Iowa.	German-American Live Stock Co.	802	German-American Live Stock Remedy		
Abbyville Kan.	Abbyville Grain Co.	789	Corn Chop	9.87	7.38
Abilene, Kan.	Abilene Milling Co.	281	Bran	16.00	4.07
do.	do. do.	282	Shorts	16.77	4.35
do.	do. do.	283	Corn Chop	9.81	4.39
do.	O. P. Fenton	786	" "	9.70	4.05
do.	A. B. Seelye Medicine Co.	1000	Universal Condition Powder		
Admire, Kan.	David Pitzer	568	Corn Chop		
Alma, Kan.	Mid-Kansas Milling Co.	746	Wheat Shorts	14.15	4.05
do.	do. do.	747	Wheat Bran	12.91	4.34
do.	do. do.	748	Corn Chop	9.18	3.75
Altamont, Kan.	J. H. Rust	752	do.		
Alton, Kan.	W. J. Kaull	874	Mixed Feed		
do.	do.	875	Corn Chop		
Altoona, Kan.	Altoona Mill Co.	529	do.	8.88	4.65
do.	Wilmoth, Lloyd & Snyder	860	do.		
Americus, Kan.	M. Toomey	596	do.	8.53	3.84

ANALYSES OF REGISTERED FEEDS—CONTINUED.

ADDRESS.	Manufacturer.	Registration No.	Feed.	Per cent. protein.	Per cent. fat.
Anthony, Kan.	Kramer Milling Co.	305	Wheat Bran	17.42	4.52
do.	do.	306	Ship Stuff	17.07	5.87
do.	do.	307	Corn Chop	8.64	3.73
Argentine, Kan.	M. L. Butcher	477	Chop or Ground Corn	8.65	4.57
Arkansas City, Kan	Arkansas City Milling Co.	687	Corn Chop	9.46	4.78
do.	do. do.	688	Shorts	18.01	4.34
do.	do. do.	689	Mixed Feed	17.53	4.09
do.	do. do.	690	Bran	16.98	4.10
do.	R. H. Brock	282	Pure Corn Chop	8.64	4.30
do.	The New Era Milling Co.	654	Corn Chop	9.28	4.75
do.	do. do.	655	Wheat Bran	16.74	3.55
do.	do. do.	656	Shorts	19.85	5.17
Ashland, Kan.	Wallingford Bros.	770	Corn Chop	9.98	3.64
do.	McElhinny & Co.	962	do.	11.33	4.14
Atchison, Kan.	Atchison Oatmeal and Cereal Co.	100	Oat Nutriment	19.25	8.30
do.	do. do.	101	Oat Bran	3.58	1.44
do.	do. do.	208	Corn and Oat Feed	6.81	2.55
do.	do. do.	209	Pure Corn Chop	8.44	3.68
do.	do. do.	942	Sunshine Prepared Poultry and Baby Stock Food	15.95	5.92
do.	do. do.	943	Kansas Ideal Dairy Feed	7.85 8.20	2.78 1.95
do.	Blair Milling Co.	176	Blair's Bran	13.01 13.36	5.08
do,	do.	177	Blair's Shorts	14.95 15.05	4.98
do.	do.	178	Blair's Corn Chop	9.29	3.99
do.	do.	179	Blair's Feed Meal or Blair's Hominy Feed	9.11	3.42
do.	The Cain Mill Co.	483	Cain's Corn Chop	9.01	3.95
do.	do.	484	Cain's Shorts	18.72	4.50
do.	do.	485	Cain's Bran	14.84	4.52
do.	do.	1082	Cain's Feed Screenings	10.19	2.37
do.	Lukens Milling Co.	180	Bran	13.87	4.94
do.	do.	181	Shorts	16.37	5.08
do.	do.	182	Corn Chop	8.24	4.20
do.	S. R. Washer Grain Co.	960	Washer's Corn Chops	8.55	3.58
do.	Mangelsdorf Bros.	1021	Standard Laying Food	18.49	3.84
do.	do.	1022	Reliable Laying Tonic	9.14	3.08
do.	do.	1023	No. 40 Chick Food	10.19	3.15
do.	do.	1024	Special Chick Food	11.04	3.69
do.	do.	1025	Imperial Chick Food	10.77	4.39
Attica, Kan.	Attica Milling Co.	472	Shorts	19.04	4.29
do.	do.	473	Corn Chop	9.32	3.72

Attica, Kan	Attica Milling Co	474	Bran	15.70	4.18
Augusta, Kan	Ward & Simpkins	552	Corn Chop	8.95	4.15
Aulne, Kan	Aulne Milling Co	497	Shorts	16.57	4.09
do.	do.	498	Bran	15.94	3.90
Axtell, Kan	D. C. O'Neil	339	Ground Corn	9.09	3.99
Barnard, Kan	Barnard Mill Co	637	Corn Chop	9.34	4.07
do.	do.	638	Shorts	15.65	3.49
do.	do.	639	Bran	18.13	4.35
Barnesville, Kan	Barnesville Milling and Stock Co	340	Corn Chop	9.10	4.31
Baxter Springs, Kan	White & Allen	559	do.	8.71	3.56
do. do.	Baxter Springs Mill and Elevator Co	1040	Mixed Corn Chop	10.62 13.52	4.28 4.50
Beattie, Kan	Peter McMahon	341	Corn Chop	8.62	4.37
Belleville, Kan	W. B. Faulkner	139	Wheat Bran	14.05	4.70
do.	do.	140	Wheat Shorts	13.15	3.01
do.	do.	141	Corn Chop and Corn Bran	8.05 7.91	3.51 ......
Beloit, Kan	Beloit Milling Co	250	Wheat Bran	15.05	4.44
do.	do.	251	Wheat Shorts	15.86	4.02
do.	do.	252	Corn Chop	9.62	4.04
Benedict, Kan	S. A. Knaus	336	do.	10.07	4.30
Bennington, Kan	Geo. C. Markley	944	Shorts	19.27	4.18
do.	do.	945	Bran	16.98	3.66
Blue Rapids, Kan	Blue Rapids Milling and Elevator Co	488	Pure Corn Chop	9.12	4.01
do.	do. do. do.	489	Pure Wheat Bran	13.92	4.63
do.	do. do. do.	490	Pure Wheat Shorts	16.56	5.13
do.	W. F. Peacock	1037	Corn and Oats Chop	9.94	4.06
Bridgeport, Kan	H. E. Peck Roller Milling Co	763	Wheat Shorts	19.08	3.90
do.	do. do. do.	764	Bran	18.58	3.84
Buhler, Kan	Buhler Mill and Elevator Co	268	Pure Hard Wheat Bran	15.08	3.18
do.	do. do. do.	269	Pure Hard Wheat Middlings	15.31	4.25
Burden, Kan	J. L. Anderson	478	Corn Chop	9.06	4.46
Burlington, Kan	D. Gerster, Excelsior Water Mill	71	Bran	16.50	4.72
do.	do. do. do.	72	Shorts	16.14	3.81
do.	do. do. do.	73	Chop	8.35	4.79
do.	Gibbon & Reid	976	Corn Chop	10.25	5.00
do.	Ira Shipley	624	do.	10.29	4.47
Burrton, Kan	H. C. Grain Co	963	H. C. Stock Food	10.41	3.67
Bushton, Kan	Bushton Roller Mills	159	Wheat Bran	16.52	4.40
do.	do. do.	160	Wheat Shorts	17.33 17.47	4.43 4.41
do.	do. do.	161	Corn Chop	10.26	4.36
Cairo, Kan	J. H. Magruder	841	Bran	18.04	3.71
do.	do.	842	Shorts	18.40	4.01
do.	do.	843	Corn Chop	9.31	4.09
Caldwell, Kan	Border Queen Mill and Elevator Co	459	do.	9.40	3.64
do.	do. do. do.	460	Shorts	16.38	4.35
do.	do. do. do.	461	Bran	15.15	4.55
do.	Caldwell Milling Co	63	Wheat Bran	16.47	4.01
do.	do. do.	64	Wheat Shorts	15.66	3.56
do.	do. do.	65	Corn Chop	8.57	4.05
Caney, Kan	Caney Grain Co	784	do.	9.43	4.17

ANALYSES OF REGISTERED FEEDS—CONTINUED.

ADDRESS.	Manufacturer.	Registration No.	Feed.	Per cent. protein.	Per cent. fat.
Caney, Kan	Caney Mill and Elevator Co	883	Bran	17.75	3.59
do.	do. do.	884	Shorts	19.50	4.94
do.	do. do.	885	Corn Chop	9.50	4.81
Canton, Kan	Canton Milling Co	342	Bran	14.11	4.13
do.	do.	343	Shorts	14.96	3.96
Cawker City, Kan	Joseph Jackson	546	Bran	14.59	4.70
do.	do.	547	Mill Feed	14.88	3.94
Cedar Point, Kan	Cedar Point Roller Mills	561	Corn Chop	10.22	4.50
do.	do.	562	Shorts	16.75	4.79
do.	do.	563	Bran	15.21	4.24
Cedar Vale, Kan	L. C. Adam Mercantile Co	524	Pure Corn Chop	9.03	4.28
Centralia, Kan	Kneedy & Leonard	982	do.	8.98	4.14
Chanute, Kan	J. N. Alcock & Co	862	Corn Chop	8.22	3.67
do.	Chanute Milling Co	450	Bran	16.90	4.61
do.	do.	451	Mill Run Bran	16.06	4.33
do.	do.	452	Shorts	14.48	3.86
do.	do.	453	Corn Chop	8.55	4.59
do.	do.	1086	Mixed Bran	15.72	5.00
do.	L. R. Tolbert	429	Corn Chop	8.09	4.11
Chapman, Kan	Carroll Milling Co	522	do.	10.17	4.28
do.	Poor & Knight	188	do.	9.08	4.30
Chautauqua, Kan	Revlett Bros	530	do.	9.70	4.38
Cheney, Kan	Cheney Milling Co	326	Bran	15.51	4.62
do.	do.	327	Shorts	15.58	4.35
do.	do.	328	Mill Run	15.31	4.29
do.	do.	329	Corn Chop	8.09	3.57
Cherokee, Kan	Cherokee Mill and Elevator Co	315	"Cherokee" Chop	8.30	4.32
do.	do. do.	316	"Lion" Bran	14.26	3.87
Cherryvale, Kan	C. D. Allen	914	Corn Chop	10.02	4.68
do.	N. Sauer Milling Co	173	Wheat Bran	15.43	4.67
do.	do.	174	Wheat Shorts	15.50	3.93
do.	do.	175	Mixed Wheat Bran and Shorts	15.60	3.84
do.	Young & Co	714	Corn Chop	8.89	4.08
Chetopa, Kan	Jim Crow Mill, W. F. McAleer	378	Mixed Corn Chop	8.24	4.48
Cimarron, Kan	O. D. Lemert	441	Corn Chop		
do.	W. F. Rhinehart	448	do.	9.74	4.23
Circleville, Kan	C. C. Conner	594	do.	8.59	3.15
Claflin, Kan	Claflin Mill and Elevator Co	196	Pure Wheat Bran	15.48	4.07
do.	do. do.	197	Shorts or Middlings	16.94	4.36

Claflin, Kan.	Universal Mill Co.	618	Wheat Bran	16.50	3.82
do.	do.	619	Wheat Shorts	18.78	4.30
Clay Center, Kan.	Clay Center Incubator Co., W. E. Smith	505	Safety Chick Feed	13.02	3.47
do.	Snell Mill and Grain Co.	198	Wheat Bran	13.84	4.37
do.	Snell Mill and Elevator Co.	199	Wheat Shorts	14.14	4.20
do.	do. do.	200	Corn Chop	7.57	4.42
do.	M. W. Willey	76	do.	9.05	3.83
do.	do.	77	Flax Seed Meal	23.77	35.54
do.	do.	78	Mixed Chop (corn, oats, corn bran)	9.88	4.58
do.	F. L. Williamson & Co.	223	Bran	12.69	4.25
do.	do. do.	224	Shorts	14.81	4.90
do.	do. do.	225	Chop	9.35	3.74
Clyde, Kan.	Clyde Milling and Elevator Co.	147	Bran	13.23	4.42
do.	do. do.	148	Shorts	13.63	4.13
do.	do. do.	149	Mill Run	13.31	4.63
do.	do. do.	150	Chop	8.98	3.99
do.	Western Elevator Co.	369	Pure Ground Corn	8.48	3.84
Coffeyville, Kan.	Crane & Foland	498	Corn Chop and Grits	8.74	4.44
do.	William Helmering	506	Corn Chop	9.45	4.19
do.	Kiddoo Milling Co.	422	Mixed Feed, Bran and Shorts	17.04	4.44
do.	The Rea-Patterson Milling Co.	18	R. P. M. Co. Bran	16.50	4.50
do.	do. do.	19	R. P. M. Co. Shorts	17.95	4.97
do.	do. do.	20	R. P. M. Co. Mixed Feed	16.49	4.46
do.	The Rea-Patterson Grain Co.	607	Corn Chop	9.07	3.24
do.	The Walton Grain Co.	821	do.	8.28	4.43
Colby, Kan.	Parrott Milling Co.	531	Bran	17.00	4.18
do.	do.	532	Shorts	17.39	3.74
do.	do.	533	Corn Chop	8.75	4.12
Colony, Kan.	C. Denton	489	do.	8.23	4.11
Columbus, Kan.	Stauffer & Commack	511	Pure Corn Chop	8.46	4.64
do.	Wesley Best & Sons	193	Wheat Bran	15.19	4.56
do.	do.	194	Shorts or Ship Stuff	14.21	3.52
do.	Fudge & Thomas	470	Silver and Gold Mixed Feed	15.37	4.70
do.	do.	471	White Shorts	12.98	2.92
do.	do.	678	Pure Corn Chop	8.61	4.27
do.	Newton Way	469	Clear Corn Chop	8.62	4.16
Concordia, Kan.	Concordia Milling Co.	124	Mixed Bran	13.42	4.59
do.	do.	125	Shorts	15.13	4.69
do.	do.	126	Mixed Feed	9.16	4.02
do.	do.	127	Corn Chop	9.28	4.18
do.	H. Lague	987	Corn Chop and Oats	10.62	3.82
do.	Perry & Gould	771	Corn Chop	9.74	4.27
do.	do.	772	Corn and Oats Chop	10.72	4.55
Conway Springs, Kan.	Conway Springs Milling Co.	855	Corn Chop	11.69	4.32
do.	do. do.	856	Shorts	17.70	4.24
do.	do. do.	857	Bran	17.78	4.07
do.	B. Strong Grain and Coal Co.	932	Corn Chop	9.44	4.18
Cottonwood Falls, Kan	Cottonwood Falls Mill and Elevator Co.	432	Shorts	14.22	3.88
do.	do. do.	516	Bran	15.58	4.44
do.	do. do.	517	Corn Chop	8.67	3.83

ANALYSES OF REGISTERED FEEDS—CONTINUED.

ADDRESS.	Manufacturer.	Registration No.	Feed.	Per cent. protein	Per cent. fat
Council Grove, Kan.	P. Broderson, Agent.	270	Corn Chop	8.78	3.81
Crestline, Kan.	E. C. Hutchinson	854	Pure Corn Chop	10.14	4.26
do.	B. F. Jaco	848	do.	9.26	3.74
Danville, Kan.	J. W. Markey	795	Markey's Corn Chop	10.35	4.34
Delavan, Kan.	Robt. T. Ray Grain Co.	849	Corn Chop	10.57	4.01
Delphos, Kan.	Will M. Chapin	494	do.	10.68	4.39
do.	do.	495	Shorts	16.82	4.47
do.	do.	496	Bran.	14.76	4.27
do.	Wright Milling Co.	257	Wheat Bran	15.35	4.57
do.	do.	258	Shorts	15.06	3.90
do.	do.	259	Corn Chop	9.35	3.79
Denison, Kan.	David Coleman.	891	do.	16.27	5.02
Dighton, Kan.	C. J. Van Keuren.	590	do.	8.54	4.08
Dillon, Kan.	Dillon Roller Mills	755	Shorts	13.55	2.78
do.	do.	756	Bran.	17.06	4.18
do.	do.	757	Corn Chop	9.12	2.42
Dodge City, Kan.	Dodge City Milling and Elevator Co.	838	Pure Corn Chop	9.81	4.21
do.	do. do. do.	990	Bran and Shorts	18.29	3.94
do.	Martin Bros.	523	Corn Chop	9.66	3.75
Downs, Kan.	A. Jackson & Co.	888	Bran.	16.17	3.39
do.	do.	889	Ship Feed (Chop)	17.75	3.53
do.	do.	890	Corn Chop	10.12	3.84
Drury, Kan.	Thrailkill Milling Co.	433	Bran.	16.96	4.02
do.	do.	434	Corn Chop	8.90	3.13
do.	do.	768	Wheat Shorts.	18.06	3.53
do.	do.	769	White Wheat Shorts.	16.11	1.81
Edna, Kan.	C. E. Page	392	Page's Pure Corn Chop	8.84	4.46
El Dorado, Kan.	Binford & Scott	621	Corn Chop	9.66	4.46
do.	Dillenbecks & Vickers	946	Corn.	....	......
do.	El Dorado Alfalfa Milling Co.	1083	Alfalfa Meal.	14.27	1.52
do.	L. H. Powell	601	Pure Corn Chop	8.58	3.68
do.	Minos West	691	Corn Chop	8.05	4.05
Elk City, Kan.	J. Johansen.	468	do.	8.93	3.74
Ellinwood, Kan.	Ellinwood Mill and Elevator Co.	518	do.	9.44	3.98
do.	do. do. do.	519	Bran ("B. 100")	16.24	4.17
do.	do. do. do.	520	Middlings ("S. 100")	17.88	4.86
do.	do. do. do.	521	Middlings ("W. S. 100")	17.00	4.29
do.	do. do. do.	604	Low-grade Flour	15.50	2.28
do.	F. W. Ludwig	585	Pure Corn Chop	9.01	4.01

Ellinwood, Kan.	**E. L. Pearson.**	981	**Corn and Alfalfa Meal.**	14.08	2.68
do.	do.	980	**Corn Chop.**	11.65	3.92
Ellsworth, Kan.	**Ellsworth Mill and Elevator Co.**	144	**Bran Offal from Wheat and Rye.**	14.91	3.94
do.	do. do.	145	Shorts Offal from Wheat and Rye.	17.51	4.65
do.	do. do.	146	Corn Chop	9.11	4.28
do.	Samuel C. Groth & Co.	353	do.	8.95	4.72
Emporia, Kan.	City Roller Mill Co.	401	Mixed Bran.	13.39	5.05
do.	do.	402	Pure Wheat Shorts	16.10	4.59
do.	do.	403	Pure Corn Chop	8.73	4.28
do.	Eagle Alfalfa Milling Co.	1016	Alfalfa Meal.	16.50	1.79
do.	Emporia Water Mills.	190	Soden's Wheat Bran	14.58	3.88
do.	do.	191	Soden's Wheat Shorts.	16.27	4.53
do.	do.	312	Soden's Corn Chop.	......	......
Enterprise, Kan.	Hoffman & Son Milling Co.	28	Bran.	14.38	4.02
do.	do. do.	29	Shorts	16.73	4.77
Erie, Kan.	R. A. Braik	383	Corn Chop	8.56	3.08
do.	H. H. Dorr & Son.	391	do.	8.35	4.13
do.	W. H. Treadway.	393	do.	8.21	4.39
Eskridge, Kan.	W. A. Ferguson	399	**Pure Corn Chop**	9.32	4.21
do.	J. E. Miller & Son	1018	**Chick Feed.**	......	......
Eudora, Kan.	W. W. Bromelsick.	463	**Wheat Bran**	15.31	4.63
do.	do.	464	**Wheat Shorts.**	12.14	2.40
do.	do.	465	**Corn Chop**	8.71	4.61
Eureka, Kan.	**Eureka City Roller Mills.**	929	do.	9.10	3.82
do.	do. do.	930	**Ship Stuff.**	14.67	3.08
do.	do. do.	931	**Bran.**	15.65	4.14
Everest, Kan.	**C. E. Sheldon**	487	**Corn Chop**	8.96	4.69
Fairport, Kan.	**G. A. Lewis.**	974	**Shorts**	17.78	2.47
do.	do.	975	**Bran.**	19.87	3.96
Florence, Kan.	**Florence City Mills.**	781	**Pure Wheat Bran.**	16.77	4.42
do.	do.	782	**Corn Chop**	9.09	4.28
do.	do.	783	**Pure Wheat Shorts**	15.89	3.01
Fontana, Kan.	**R. L. Gordon.**	680	**Corn Chop**	8.11	4.27
Ford, Kan.	**L. K. Van Horne.**	548	do.	......	......
Fort Scott, Kan.	**Goodlander Milling Co.**	377	**Mixed Bran and Shorts**	14.35	4.04
do.	do. do.	378	**Shorts**	15.01	4.24
do.	do. do.	379	**Middlings.**	15.20	1.83
do.	do. do.	380	**Corn Chop**	8.77	4.31
Fowler, Kan.	**William Andis.**	602	do.	9.58	4.11
do.	**Hatch Bros.**	462	Pure Alfalfa Meal.	15.48	2.18
Frankfort, Kan.	**Frankfort Feed Mill Co.**	651	Ground Corn Chop.	8.87	3.78
do.	do. do.	652	Ground Speltz	13.72	2.30
do.	**H. C. White.**	657	Corn Chop ¾, Ground Spelts ¼	10.33	3.27
do.	do.	658	Ground Corn.	8.41	3.60
Fredonia, Kan.	**Fredonia Linseed Oil Works.**	606	Old Process Linseed Oil Meal.	31.98	14.12
do.	A. Otto	685	**Corn Chop**	8.28	4.43
Galena, Kan.	Galena Mill and Elevator Co.	776	do.	......	......
do.	**H. L. Jaqueth.**	608	do.	9.18	4.80
do.	**H. C. Loucks.**	807	do.	9.01	4.84
do.	**Sol. Ryan**	1005	**Mixed Feed**	13.88	3.47

ANALYSES OF REGISTERED FEEDS—CONTINUED.

ADDRESS.	Manufacturer.	Registration No.	Feed.	Per cent. protein	Per cent. fat
Galesburg, Kan.	William Moore	414	Corn Chop	8.04	4.17
Garden City, Kan.	Garden City Mill and Elevator Co.	549	Clear Corn Chop	10.45	4.60
Gardner, Kan.	Ward & Fluke	845	Ground Corn	7.91	4.27
Garfield, Kan.	Garfield Cooperative Co.	871	Corn Chop	9.28	4.81
do.	do. do.	872	Mixed Bran and Shorts	17.45	3.04
Garland, Kan.	S. J. Bryant	221	Corn Chop	8.27	4.92
do.	do.	222	Corn Bran	9.62	3.49
Garnett, Kan.	W. O. Decker & Co.	611	Corn Chop	9.13	4.39
do.	do.	612	Shorts	15.51	4.08
do.	do.	613	Bran	15.09	4.58
Girard, Kan.	C. Hitz & Son	584	Wheat Bran	15.87	4.23
do.	do.	585	Corn Chop	8.30	3.96
do.	do.	586	Wheat Shorts	15.85	4.25
do.	Leigh & Gerken	751	Corn Chop	8.51	4.05
do.	Morrow & Taaffe	970	do.	9.02	4.08
Glen Elder, Kan.	Nash & Kaull	877	Bran	17.38	3.77
do.	do.	878	Shorts	20.18	4.90
Goessel, Kan.	Goessel Milling Co.	115	Bran	14.41	4.77
do.	do.	116	Shorts	14.43	3.71
Goodland, Kan.	Bartholomew & Jayne	491	Barley Chop	12.31	2.04
do.	do. do.	492	Corn Chop	8.89	3.49
do.	J. G. Hamilton	605	do.	9.66	3.94
do.	King Manufacturing Co.	811	King Cholera Remedy, No. 1	8.14	0.64
do.	do. do.	812	King Cholera Remedy, No. 2	8.60	1.16
do.	do. do.	813	King Condition Powders	22.51	6.49
Great Bend, Kan.	Barton County Flour Mills Co.	363	Bran	15.28	4.13
do.	do. do.	364	Shorts	17.63	4.44
do.	do. do.	365	White Shorts	16.91	4.06
do.	do. do.	366	Mixed Feed	16.61	4.14
do.	do. do.	367	Corn Chop	9.53	4.02
do.	Moses Bros. Mill and Elevator Co.	330	Bran	15.18	4.39
do.	do. do.	331	Shorts	16.60	4.06
do.	Moses Bros. Grain Co.	332	White Shorts	17.27	3.71
do.	Moses Bros. Mill and Elevator Co.	333	Mixed Feed	17.16	4.12
do.	do. do.	415	100 Pound Corn Chop	9.25	4.41
do.	Walnut Creek Milling Co.	201	Wheat Bran	14.98	4.01
do.	do. do.	202	Wheat Shorts	18.11	4.85
do.	do. do.	203	Mixed Feed	15.12	4.34
do.	do. do.	204	Corn Chop	8.98	3.64

Greeley, Kan.	John Weaver, Greeley Mills	550	Pure Corn Chop	8.44	4.18
Greensburg, Kan.	J. M. Kelley	291	Kelley's Best Chop	10.43	4.14
Grenola, Kan.	Hand & Miller Bros.	528	Stockman's Pride (chop)	....	......
Gypsum, Kan	Teichgraeber Bros.	97	Bran	14.70	4.88
do.	do.	98	Shorts	15.81	4.88
do.	do.	99	Corn Chop	9.97	4.70
Halstead, Kan.	Halstead Milling and Elevator Co	37	Bran	14.47	4.35
do.	do. do.	38	Shorts or Ship Stuff	15.20	3.98
do.	do. do.	39	Corn Chop	9.25	4.04
Hanover, Kan	Ed Mueller & Son	543	Pure Wheat Shorts	15.71	5.36
do.	do.	544	Pure Wheat Bran	14.20	5.07
do.	do.	545	Pure Corn Chop	10.16	3.68
Hanston, Kan	D. J. Hooley	586	"D. J. H." (barley and corn)	....	......
Harlan, Kan	Harlan Milling Co	337	Pure Wheat Bran	14.82	4.25
do.	do.	338	Pure Wheat Shorts	15.23	4.36
do.	do.	339	Pure Corn Chop	9.62	3,70
Harper, Kan	Harper Mill and Elevator Co	578	Mill Run	16.08	4.51
do.	do. do.	579	Pure Corn Chop	9.29	4.71
do.	do. do.	580	Ship or Shorts	18.31	4.66
do.	do. do.	581	Straight Wheat Bran	16.39	3.94
Hartford, Kan	T. O. Gibbon	863	Corn Chop	8.15	3.69
do.	O'Connor & Stratton	551	do.	8.45	3.77
Harveyville, Kan.	Garinger Bros	443	do.	8.91	3.92
Haven, Kan	Bushman, Welk & Co.	311	Wheat Bran	16.67	4.14
do.	do.	313	Corn Chop	9.82	3.79
do.	do.	424	Shorts	17.82	5.44
Hays, Kan	Streat H. Cox	567	Corn Chop	10.05	3.72
do.	I. M. Yost Milling Co.	608	Pure Shorts	21.25	4.40
do.	do.	609	Pure Bran	20.88	4.13
do.	do.	964	Corn Chop	9.77	4.19
Helmick, Kan	J. O. Rochat	507	do.	8.76	3.97
Herndon, Kan	Malone & Wenzel	496	Shorts	16.26	4.56
do.	do.	500	Bran	16.00	4.51
do.	do.	501	Corn Chop	10.56	4.74
Hiawatha, Kan.	Hiawatha Milling Co.	253	Wheat Bran	14.02	4.56
do.	do.	254	Wheat Shorts	14.75	4.77
do.	do.	255	Corn Chop	9.29	4.28
do.	Reliable Stock Powder Co. (B. E. Sipe)	1001	Reliable Stock Powder	....	......
Hill City, Kan	Graham Co. Mill and Elevator Co	416	Chop	11.21	4.27
do.	do. do.	417	Bran (wheat)	15.70	4.16
do.	do. do.	418	Shorts (wheat)	15.63	3.45
do.	do. do.	435	Barley Chop	....	......
Hillsboro, Kan	Ebel Bros	894	Red Shorts (pure)	18.17	4.64
do.	do.	895	Corn Chop (pure)	9.75	3.43
do.	do.	896	Bran	15.37	3.67
do.	do.	897	White Shorts	17.67	3.50
do.	John A. Klaassen	924	Wheat Shorts	17.45	4.29
do.	do.	925	Corn Chop	9.99	3.64
do.	do.	926	Wheat Bran	15.87	3.67

ANALYSES OF REGISTERED FEEDS—CONTINUED.

ADDRESS.	Manufacturer.	Registration No.	Feed.	Per cent. protein	Per cent. fat
Holton, Kan.	Sarbach Grain Co.	949	Corn Chop	......	......
Holyrood, Kan.	Holyrood Milling Co.	816	Pure Wheat Shorts	17.77	4.37
do.	do. do.	817	Pure Wheat Bran	17.50	4.05
Hope, Kan.	Emil Brunner	986	Bran Shorts or Mill Run	17.19	3.84
do.	do.	985	Corn Chop	11.60	4.23
Hoyt, Kan.	John McClune	785	do.	8.19	4.80
Hudson, Kan.	Stafford Co. Flour Mills	865	Bran	17.17	3.55
do.	do. do.	866	Mixed Feed	18.17	4.00
do.	do. do.	867	Shorts	19.97	4.54
do.	do. do.	868	Corn Chop	10.18	5.65
Humboldt, Kan.	Dickinson Bros.	274	do.	7.56	3.68
do.	Humboldt Water Mill	92	Wheat Bran	16.00	4.19
do.	do.	93	Wheat Shorts	16.66	5.19
do.	do.	94	Corn Chop	7.70	4.28
do.	do.	95	Corn and Oat Chop	9.40	5.06
Hutchinson, Kan	Robert Bailey	885	Corn Chop	10.08	3.76
do.	Forsha Milling Co.	525	Shorts	18.13	4.96
do.	do.	526	Bran	16.67	4.40
do.	Hutchinson Mill Co.	571	do.	15.86	4.11
do.	do.	572	Shorts	19.96	5.39
do.	do.	573	White Shorts	15.88	3.05
do.	do.	574	Corn Chop	9.28	3.52
do.	Kansas Grain Co.	216	do.	8.06	4.32
do.	Wm. Kelly Milling Co.	272	Bran	15.54	4.46
do.	do.	273	Shorts	18.81	5.41
do.	Monarch Milling Co.	279	Bran	14.68	4.58
do.	do.	280	Shorts	15.43	4.47
do.	Rock Island Mill Co.	285	Pure Corn Chop	9.08	4.08
do.	do.	527	Corn Bran	......	......
do.	J. A. Sickman & Co.	588	"A. C." (Alfalfa and Corn)	10.98	4.32
do.	do.	662	"P. C." (Pure Corn)	8.82	3.86
do.	Young & Sons	368	Young's Mixed Chicken Feed	8.73	3.25
do.	do.	823	Corn Chop	9.67	3.92
Independence, Kan.	Bowen & Lewis	591	do.	8.90	3.85
do.	do.	592	Oats Chop	9.72	4.63
Independence and Elk City	Bowen Milling Co.	479	Mill Run Feed or Bran	15.51	4.68
do. do.	do.	480	Shorts or Middlings	18.44	5.39
do. do.	do.	481	Bran	14.40	4.53
do. do.	do.	482	Corn Chop	9.48	4.65

Independence, Kan.	Johnston & Allen.	600	Corn Chop	8.86	3.92
do.	H. L. Theiss	871	do.	9.27	4.11
Inman, Kan	Inman Milling Co.	181	Bran.	15.01	3.61
do.	do. do.	256	Shorts	16.84	4.12
Iola, Kan.	R. R. Claiborne.	721	Corn Chop	8.71	4.57
Jetmore, Kan	A. H. Ling.	195	do.	8.39	4.13
Jewell City, Kan.	Jewell Milling Co.	381	do.	8.68	4.58
do.	do. do.	382	Shorts	15.05	4.11
do.	do. do.	384	Bran.	14.25	4.61
Junction City, Kan.	Hogan Milling Co.	394	do.	13.98	4.41
do.	do. do.	395	Shorts	14.87	3.85
do.	C. E. Stevens	972	Pure Corn Chop	10.02	3.93
do.	Tyler & Co., Aurora Mills.	502	Bran.	16.49	4.61
do.	do. do.	503	White Shorts.	17.49	4.84
do.	do. do.	504	Corn Chop	9.04	3.86
Kansas City, Kan.	Armour Packing Co.	354	Helmet Brand Ground Meat Meal	62.48	12.89
do.	do. do.	694	Helmet Brand Ground Bone.	25.26	0.80
do.	do. do.	695	Helmet Brand Blood Meal (fine and granulated).	87.83	0.23
do.	Blacker Grain Co.	440	Corn Chop	8.21	4.24
do.	Crescent Cereal Co.	864	do.	8.36	3.98
do.	Joe A. Stahl Hay Co.	566	do.	9.33	3.98
do.	Alfred Weston & Co.	588	Pure Corn Chop	8.40	4.02
Kensington, Kan.	Kensington Mill Co.	554	Shorts	16.88	3.90
do.	do. do.	555	Bran.	15.98	3.90
do.	do. do.	556	Ground Corn.	9.38	3.13
do.	do. do.	557	Ground Wheat.	13.08	2.48
Kingman, Kan.	Kingman Milling Co.	285	Bran (wheat)	15.47	4.63
do.	do. do.	286	Shorts	17.22	5.08
do.	do. do.	287	Corn Chops.	9.17	3.78
Kinsley, Kan.	Fravel & Lewis.	640	Corn Chop	......	......
Kirwin, Kan.	J. W. & C. R. Jackson	597	Bran.	16.42	3.77
do.	do. do.	598	Ship Stuff	18.13	3.95
do.	do. do.	599	Corn Chop	9.92	3.93
La Cygne, Kan.	Cartwell & Potter	584	do.	......	......
La Harpe, Kan.	Adams & Co.	276	do.	7.80	3.96
do.	S. S. Forney	310	Straight Corn Chop	8.55	4.60
do.	International Drug Co.	740	"Big 4" Stock Food	19.37	4.62
Lakin, Kan.	C. H. Waterman	869	Corn Chop	......	......
Larned, Kan.	Albert Anderson.	950	do.	7.98	2.47
do.	H. G. Gabel & Sons.	641	Mixed Feed	19.18	3.58
do.	do. do.	642	Shorts	18.75	3.09
do.	do. do.	643	Corn Chops.	10.27	4.56
do.	do. do.	644	Bran.	17.75	3.97
do.	Grant Milling Co.	851	do.	17.87	3.39
do.	do. do.	852	Shorts	15.67	4.24
do.	do. do.	853	Corn Chops.	10.82	3.98
do.	do. do.	989	Mixed Feed	19.85	3.68
do.	Lafe Lee.	537	Corn Chop	9.68	4.81
Lawrence, Kan.	Bowersock Mills and Power Co.	242	Pure Wheat Bran	14.50	4.11
do	do. do.	243	Pure Wheat Shorts.	15.38	3.87

ANALYSES OF REGISTERED FEEDS—CONTINUED.

ADDRESS.	Manufacturer.	Registration No.	Feed.	Per cent. protein	Per cent. fat
Lawrence, Kan.	Bowersock Mills and Power Co.	244	Pure Corn Chop	8.25	3.57
do.	A. C. Gibson	560	do.	9.29	4.07
do.	F. Gleed	984	do.	8.90	4.88
do.	E. B. Gorsuch	108	Corn Chop	8.19	5.00
do.	Pierson Milling Co.	217	Bran	12.99	4.66
do.	do. do.	218	White Shorts	10.57	2.13
do.	Underwood & Jones	918	Corn Chop	9.57	4.19
Leavenworth, Kan.	Ashby & Son	157	do.	8.89	3.60
do.	do.	158	Corn Bran	8.02	5.98
do.	M. A. Kelley	598	Corn Chops	8.89	4.82
do.	Kelley & Lysle Milling Co.	117	Pure Wheat Bran	13.24	4.52
do.	do. do.	118	Pure Wheat Shorts	16.37	5.77
do.	Leavenworth Milling Co.	879	Shorts	18.70	4.43
do.	do. do.	880	Bran	16.53	3.97
do.	Taylor Corn Mill Co.	661	Chop	8.58	4.06
Lebanon, Kan.	Lebanon Mill and Elevator Co.	564	Pure Wheat Shorts	17.65	4.07
do.	do. do.	565	Wheat Bran	16.73	3.83
do.	do. do.	739	Corn Chop	8.99	3.58
Lebo, Kan.	Geo. E. Ott	558	do.	8.70	4.18
Lecompton, Kan.	C. L. Walters	804	do.	....	......
Lehigh, Kan.	Groening Bros.	778	do.	9.60	4.08
do.	do.	779	Bran	16.75	3.51
do.	do.	780	Shorts	17.25	4.17
Lenora and Edmond, Kan.	Long & Goodman	722	do.	15.97	4.58
do. do.	do.	723	Bran	14.64	3.78
Le Roy, Kan.	Le Roy Milling Co.	955	Corn Chop	9.13	4.14
do.	do.	956	Shorts	14.50	3.01
do.	do.	957	Bran	15.40	3.96
Lewis, Kan.	James F. Malin	882	Corn Chop	9.45	3.46
Lincoln, Kan.	J. C. Cooper	773	do.	....	......
do.	Lincoln Roller Mills	396	White Shorts	13.68	1.56
do.	do. do.	397	Shorts	16.52	4.18
do.	do. do.	398	Bran and Shorts	16.19	4.36
Lindsborg, Kan.	Theo. Teichgraeber	52	Wheat Bran	12.99	4.07
do.	do.	53	Shorts	16.20	4.98
do.	do.	54	Pure Corn Chop	9.81	4.49
do.	Lindsborg Milling and Elevator Co.	90	Wheat Bran	14.31	4.35
do.	do. do.	91	Wheat Shorts	17.13	4.94
Logan, Kan.	Bowman Bros.	515	Corn Chop	9.74	3.78

Logan, Kan	C. H. Shurtz	294	Shorts and Bran (mixed)	14.27	2.83
do.	do.	295	Corn Chop	9.39	3.14
Longton, Kan	H. Mongridge	260	do.	....	......
Lorraine, Kan	Henry M. Groth	466	do.	11.84	3.49
Lost Springs, Kan	Lost Springs Milling and Elevator Co.	711	Shorts	15.70	3.58
do.	do. do. do.	712	Bran	15.96	3.80
Louisburg, Kan	M. Reed	738	Corn Chop	8.17	3.18
Lucas, Kan	J. Q. Cooper & Co	979	Shorts and Bran	20.45	4.10
Lyons, Kan	Central Kansas Milling Co	314	Mill Run	15.81	4.31
do.	do. do.	317	Shorts	16.09	3.75 3.78
do.	do. do.	318	Bran	15.77	4.38
do.	do. do.	589	Corn Chop	10.16	3.85
do.	Lyons Milling Co	34	Bran	15.67	4.32
do.	do. do.	35	Shorts	17.78	5.52
do.	do. do.	36	Corn Chop	9.35	4.03
McCracken, Kan	McCracken Mill and Elevator Co	900	Wheat Shorts	14.27	2.25
do.	do. do. do.	901	Wheat Bran	13.67	3.53
do.	do. do. do.	902	Bran and 10 per cent. Screenings, Chop	17.82	3.03
McCune, Kan	Wm. Redpath Grain Co	653	Wm. Redpath Grain Co.'s Pure Corn Chop	8.74	4.09
McLouth, Kan	B. C. Ragan & Sons	372	Corn Chop	8.24	2.95
McPherson, Kan	Colburn Bros	30	Bran	14.63	4.41
do.	do.	31	Shorts	16.33	5.16
do.	do.	32	Corn Chop	9.74	4.51
do.	New Pearl Milling Co	665	Shorts	17.06	4.85
do.	do. do.	666	Bran	15.47	4.33
do.	Cyrus E. Roberts	991	Demce Chick Food	12.33	3.30
do.	Wall-Rogalsky Milling Co	106	Bran	15.08	4.54
do.	do. do.	107	Shorts	16.56	5.04
do.	do. do.	444	Pure Corn Chop	9.25	3.57
Manhattan, Kan	Manhattan Milling Co	96	Corn Chop	8.87	4.04
do.	do. do.	277	Bran	13.84	4.50
do.	do. do.	278	Shorts	14.87	4.64
do.	Geo. T. Fielding & Son	284	Corn Chop	8.95	4.10
do.	Long-Barner Milling Co	728	Bran	15.33	3.80
do.	do. do.	729	Corn Chop	8.82	4.24
do.	do. do.	730	Shorts	19.90	4.07
Mankato, Kan	W. Kier	886	Corn Chop	....	......
Marion, Kan	Cottonwood Valley Mills	81	Bran	14.61	4.46
do.	do. do.	82	Shorts	14.40	3.56
do.	do. do.	83	Corn Chop	8.96	3.96
do.	Ehrlich & Sons	767	do.	....	......
Marquette, Kan	Marquette Roller Mills Co	582	Bran	13.09	4.06
do.	do. do.	583	Shorts	13.56	4.49
Marysville, Kan	Perry Hutchinson	798	do.	15.89	5.61
do.	do.	799	Bran	14.11	3.87
May, Kan	Clark Bros	164	Corn Chop	....	......
Meade, Kan	H. H. Butler	226	Barley Chop	12.05	2.26
do.	do.	227	Chop	9.44	4.17
do.	James Wilson	650	Corn Chop	9.76	4.16

ANALYSES OF REGISTERED FEEDS—CONTINUED.

ADDRESS.	Manufacturer.	Registration No.	Feed.	Per cent. protein.	Per cent. fat.
Medicine Lodge, Kan.	W. R. Forsythe	33	Corn Chop	10.57	4.84
Meriden, Kan.	Meriden Elevator Co.	800	do.	8.35	3.51
Minneapolis, Kan.	Farmers' Elevator Co.	134	do.	8.95	4.12
do.	J. H. Gentry	903	do.	9.98	4.20
do.	John Hartley	679	do.	8.98	3.95
do.	Jackman Roller Mills	84	Pure Wheat Bran	14.28	4.46
do.	do. do.	85	Pure Wheat Middlings	16.64	4.59
do.	Minneapolis Mill and Elevator Co.	892	Bran	16.50	3.35
do.	do. do. do.	904	Shorts	17.04	3.57
do.	do. do. do.	905	Corn Chop	9.61	3.70
Moline, Kan.	Frank Webb	907	do.	9.42	4.09
Montana, Kan.	E. E. Lugenbeal	449	Pure Corn Chop	8.21	3.57
Moran, Kan	Moran Grain Co.	919	Corn Chop	....	......
Morganville, Kan.	Morganville Mill and Elevator Co.	388	Wheat Shorts	13.64	4.53
do.	do. do. do.	389	Wheat Bran	12.80	4.61
do.	do. do. do.	390	Corn Chop	8.54	3.87
Morland, Kan	Morland Milling and Grain Co.	724	do.	10.07	4.46
do.	do. do.	725	Bran	18.15	3.97
do.	do. do.	726	Shorts	16.72	2.47
Morrill, Kan.	H. R. Melendy	741	Corn Chop	9.65	4.02
Mound City, Kan.	W. A. Carpenter	376	Carpenter's Corn Chop	7.91	4.03
Moundridge, Kan.	Alta Milling Co.	412	Bran	15.15	4.83
do.	do.	413	Shorts	13.80	3.09
do.	Moundridge Milling Co.	58	do.	16.26	4.58
do.	do. do.	57	Bran	15.58	3.88
do.	do. do.	59	Mill Run or Mixed Feed	15.09	5.04
Mulvane, Kan.	Neasly & Rucker.	119	Bran	13.26	4.25
do.	do.	120	Shorts or Ship	16.06	4.55
do.	do.	121	Chop	8.76	4.26
Neodesha, Kan.	Bauman Grain Co.	467	Bauman's Pure Chop	7.98	4.28
do.	Land Milling Co.	87	Bran	15.57	4.65
do.	do.	88	Shorts	17.09	4.52
do.	do.	89	Corn Chop	7.98	4.21
do.	do.	1088	Mixed Feed	15.57	4.64
do.	Sharp & Son	475	Sharp's Straight Corn Chop	8.84	4.61
Neosho Falls, Kan.	Farmers' Roller Mills	684	Corn Chop	8.87	3.50
Ness City, Kan.	D. E. Bondurant	910	do.	9.68	4.32
New Albany, Kan.	Robert Mooney	678	do.	8.95	4.17
do.	New Albany Roller Mills	685	Shorts	14.04	3.45

New Albany, Kan.	New Albany Roller Mills	686	Wheat Bran	14.24	4.74
Newton, Kan	P. M. Claassen	569	do.	15.48	4.88
do.	do.	570	Wheat Shorts	12.83	2.42
do.	Eagle Milling Co.	55	Bran	16.54 7.06	4.25 4.02
do.	Eagle Milling Co.	56	Shorts	15.49 18.80	3.46 4.77
do.	Newton Alfalfa Mills	808	Pure Alfalfa Meal	16.47	2.20
do.	Newton Milling and Elevator Co	42	Bran	15.88	4.39
do.	do. do.	43	Shorts	17.16	4.82
do.	do. do.	44	Corn Chop	9.80	3.53
do.	Nurse & Lawry	753	Corn and Oats Chop	10.80	4.48
do.	do.	754	Corn Chop	10.17	4.54
Niles, Kan.	Niles Grain Co	787	do.	11.01	3.50
do.	Thos. Lockhart	958	do.	10.53	4.04
North Topeka, Kan	J. B. Billard	706	do.	9.50	4.76
do.	do.	707	Mixed Chop	9.41	4.42
do.	do.	708	Mixed Bran and Chop	12.58	4.15
do.	do.	709	Rye Bran	18.48	2.82
do.	do.	710	Corn Bran	9.33	7.22
Norton, Kan	Farmers Milling and Elevator Co	675	Corn Chop	9.54	3.77
do.	do. do.	676	Shorts	17.48	4.16
do.	do. do.	677	Bran	15.86	4.17
Norwich, Kan	Norwich Mill and Grain Co	713	Corn Chop	9.08	4.10
Oakley, Kan.	Oakley Milling Co.	610	Mill Run or Mixed Feed	19.05	4.26
Oberlin, Kan	Oberlin Roller Mills	404	Bran	15.15	3.87
do.	do. do.	405	Shorts	16.87	4.11
do.	do. do.	406	Corn Chop (with 2 per cent. corn bran)	10.82	4.85
Oketo, Kan.	H. R. Chapman & Co	622	Bran	14.87	4.81
do.	do. do.	623	Shorts	14.45	4.16
Olathe, Kan	T. G. Graham	296	Corn Chop	8.49	3.51
Onaga, Kan	S. P. Taylor	86	do.	7.83	4.17
Opolis, Kan.	James Denton	476	do.	8.61	3.98
Osage City, Kan.	Arthur Adams	133	do.	8.18	4.44
do.	Osage City Grain and Elevator Co	45	do.	8.07	4.07
Osborne, Kan	W. B. Foy	906	do.	9.83	3.69
do.	Solomon Valley Milling Co.	512	"O" (wheat bran)	16.17	3.91
do.	do. do.	513	"O" (wheat shorts)	19.17	4.49
do.	do. do.	514	Corn Chop	9.01	4.36
Oswego, Kan.	J. S. Bottenfield	664	do.	8.07	3.60
do.	J. M. Fleming	192	Fleming's Corn Chop	8.53	4.68
do.	Oswego Milling Co.	298	Mill Run Bran	14.45	4.57
do.	do. do.	299	Wheat Shorts	18.65	3.40
do.	do. do.	300	Corn Chop	8.11	4.02
do.	Pearl Roller Mill Co.	355	Mixed Feed	14.08	4.77
do.	do. do.	410	Corn Chop	7.99	3.49
do.	do. do.	411	Mill Run	12.14	1.64
do.	Oswego Seed and Grain Co.	967	Corn Chop	10.19	3.82
do.	do. do.	998	Mixed Feed	11.35	3.59
Ottawa, Kan	Forest Park Milling Co	951	Bran		

ANALYSES OF REGISTERED FEEDS—CONTINUED.

ADDRESS.	Manufacturer.	Registration No.	Feed.	Per cent. protein.	Per cent. fat.
Ottawa, Kan.	Forest Park Milling Co.	952	Shorts	......	......
do.	do. do.	953	Corn Chop	......	......
do.	Williams-Wilson Grain Co.	909	do.	8.15	3.67
Oxford, Kan.	Mitchell Mill Co.	356	Wheat Bran	15.19	4.56
do.	do.	357	Wheat Shorts	15.69	4.35
do.	do.	358	Corn Chop	8.86	4.50
Ozawkie, Kan.	M. A. Wilson	969	do.	8.60	4.05
Paola, Kan.	R. Ewbank & Co.	207	Pure Corn Chop	8.10	3.92
do.	E. T. Fowler	142	Corn Chop	8.90	4.45
do.	do.	143	Corn Bran	6.13	2.52
do.	Voglesong & Hamlin	40	Bran	15.08	4.24
do.	do.	41	Shorts	15.03	4.06
do.	do.	261	Corn Chop	8.78	3.96
Parsons, Kan.	J. C. Burgess	636	do.	8.76	4.36
do.	Cornish & Slane, Globe Feed Mill	587	Pure Corn Chop	8.40	3.54
do.	Hoke Bros.	169	Bran	13.74	4.75
do.	do.	170	Shorts	12.23	2.80
do.	do.	171	Corn Chop	8.09	3.65
do.	do.	172	Mixed Chicken Feed	8.80	2.86
do.	W. H. Jardine	1008	Electric Mixed Feed	11.72	4.12
do.	J. W. McKierman	129	Exchange Mill Chicken Feed	9.18	3.76
do.	do.	130	Exchange Mill Corn Chop	8.08	4.38
do.	G. W. Thurston	309	Duke's Mixture	11.19	4.26
Partridge, Kan.	W. M. French	797	Corn Chop	9.94	4.50
Paxico, Kan.	Paxico Milling Co.	214	Paxico Milling Co.'s "Pure Wheat Bran"	12.47	4.43
do.	do.	215	Paxico Milling Co.'s White Shorts	12.64	3.85
Peabody, Kan.	Janett & Moffitt	154	Wheat Bran	15.46	4.67
do.	do.	155	Wheat Shorts	15.77	4.91
do.	do.	156	Corn Chop	8.87	3.28
do.	W. A. Sterling	821	do.	9.69	4.07
Peru, Kan.	Peru Milling and Elevator Co.	700	Wheat Shorts	15.27	3.53
do.	do. do.	701	Corn Chop	8.72	4.37
do.	do. do.	702	Wheat Bran	17.14	4.71
Phillipsburg, Kan.	Phillipsburg Mill and Elevator Co.	630	Wheat Shorts or Middlings	18.38	3.95
do.	do. do.	631	Corn Chop	9.92	4.55
do.	do. do.	632	Wheat Bran	17.00	4.20
do.	McIlvain Grain and Coal Co.	961	Corn Chop	......	......
Pittsburg, Kan.	L. Belknap	70	do.	9.07	5.69
do.	L. Belknap	1085	Belknap's Mixed Feed	14. 4	4.02

Pittsburg, Kan.	Pittsburg Elevator Co.	79	Pittsburg Elevator Mixed Feed.	13.29	3.28
do.	do. do.	80	Pittsburg Elevator Chop	7.81	4.57
do.	Pittsburg Modern Milling Co.	184	Bran (98 lbs.)	15.52	4.54
do.	do. do.	185	Shorts (98 lbs.)	14.71	3.50
do.	do. do.	186	Mixed Feed or Mill Run (98 lbs.)	15.24	3.71
do.	do. do.	187	Corn Chop	8.51	4.98
Plainville, Kan.	Plainville Mill and Elevator Co.	539	Mixed Feed	18.26	4.32
do.	do. do.	540	Shorts	19.61	4.67
do.	do. do.	541	Bran	17.17	4.36
do.	do. do.	542	Corn Chop	10.21	3.50
Pleasanton, Kan.	The Blaker Milling Co.	301	Wheat Bran	14.19	4.32
do.	do. do.	302	Wheat and Corn Bran	13.45	5.40
do.	do. do.	303	Wheat Shorts	16.70	4.85
do.	do. do.	304	Corn Chop	7.86	4.10
do.	M. V. Bradley	928	do.	......	......
Pratt, Kan.	Pratt Mill and Elevator Co.	407	Wheat Bran	15.47	4.34
do.	do. do.	408	Corn Chop	9.25	4.44
do.	do. do.	409	Wheat Shorts	17.46	5.33
do.	Geo. S. Scantlin & Co.	983	Corn Chop	10.20	4.48
Protection, Kan	Alva Mill and Elevator Co.	870	do.	8.60	3.78
do.	Wuchter & McCracken	674	do.	10.77	4.28
Quenemo, Kan.	S. F. Lester	553	do.	8.84	4.05
do.	Quenemo Milling Co.	911	Bran	17.42	4.15
do.	do. do.	912	Corn Chop	7.89	3.61
do.	do. do.	913	Shorts	16.83	4.00
Rosedale, Kan.	Chas. Engler	182	Corn Chops	8.44	3.49
do.	Southern Milling Co.	109	Corn Chop	8.67	3.81
Russell, Kan.	Russell Milling Co.	436	Wheat Bran	15.84	4.28
do.	do. do.	437	Shorts	18.54	5.17
St. John, Kan	P. F. Fox & Co.	663	Corn Chop	8.38	3.39
St. Marys, Kan.	Byrnes & Co.	758	do.	8.92	3.97
Salina, Kan.	John Finley	682	Mixed Feed	12.69	4.23
do.	do.	683	Corn Chop	9.18	4.62
do.	Lee-Warren Milling Co.	21	Winter Wheat Bran	14.49	3.97
do.	do. do.	22	Winter Wheat Middlings	16.56	4.56
do.	Edward Lotz	122	Corn and Oats Chop	9.02	4.41
do.	do.	123	Corn Chop	8.91	4.44
do.	do.	275	Mixed Feed	12.03	4.42
do.	Shellabarger Mill and Elevator Co.	9	Bran "S"	16.70	4.26
do.	do. do.	10	Middlings "S"	17.75	4.60
do.	do. do.	11	Mixed Feed "S"	14.05	4.30
do.	do. do.	12	Corn Chop "S"	10.60	3.95
do.	Western Star Mill Co.	24	Star Winter Wheat Bran	16.07	4.06
do.	do. do.	25	Star Winter Wheat Middlings	17.24	4.74
do.	do. do.	26	Star Corn Chop	8.52	3.82
do.	do. do.	27	Star Corn and Oats Chop	9.28	4.39
Sawyer, Kan	Bozeman & Francis	916	Shorts	13.75	2.40
do.	do. do.	917	Bran	15.77	3.87
Scott City, Kan.	L. & M. Mercantile Co.	973	Corn Chop	10.08	4.14
Sedan, Kan.	Webb Livery Co.	978	do.	9.12	3.51

ANALYSES OF REGISTERED FEEDS—CONTINUED.

ADDRESS.	Manufacturer.	Registration No.	Feed.	Per cent. protein.	Per cent. fat.
Sedgwick, Kan.	G. Barkemeyer	128	B's Corn Chop	9.19	4.07
do.	Wm. Finn	352	Corn Chop	8.76	3.79
Seneca, Kan.	H. Eichenlaub	749	Corn and Oats Chop	10.00	4.12
do.	do.	750	Corn Chop	8.73	4.27
Severance, Kan.	Ebeling & Laverantz	346	Wheat Bran	13.12	5.38
do.	do. do	347	Shorts	9.21	2.12
do.	do. do.	348	Corn Chop	7.86	4.11
Severy, Kan.	A. M. Brandt	927	do.	10.15	3.10
Shady Bend, Kan.	Shady Bend Mill and Elevator Co.	667	Mixed Feed	17.02	3.99
do.	do. do.	668	Corn Chop	9.40	3.80
Sibley, Kan.	E. O. Karnes	784	Pure Corn Chop	8.81	3.73
Simpson, Kan.	Simpson Milling Co.	66	Bran	13.33	4.69
do.	do. do.	67	Shorts	15.51	4.84
do.	do. do.	68	Ear Corn Chop	8.28	3.48
do.	do. do.	69	Corn Chop	9.49	4.39
Smith Center, Kan.	Smith Center Mill, Elevator and Light Co.	359	Wheat Bran	14.09	4.05
do.	do. do. do.	360	Shorts	16.60	4.54
do.	do. do. do.	727	Corn Chop	9.33	4.20
South Haven, Kan.	Wm. B. Hicks	385	Bran	14.56	4.29
do.	do.	386	Shorts	17.04	4.90
do.	do.	387	Corn Chop	9.48	3.39
Stafford, Kan.	Larabee Flour Mills Co.	110	Larabee's Bran	14.29	4.68
do.	do. do.	111	Larabee's Shorts	16.46	4.86
do.	do. do.	112	Larabee's Mixed Feed	15.41	4.64
do.	do. do.	113	Larabee's Sterling Feed	12.01	1.65
do.	do. do.	114	Larabee's Corn Chop	9.41	3.85
Sterling, Kan.	Henry J. Arnold	46	Bran	15.17	4.05
do.	do.	47	Shorts	18.13	4.85
do.	do.	48	Shorts and Bran Mixed	15.50	4.69
do.	do.	49	Corn Chop	8.24	3.85
do.	H. M. Lloyd	681	do.	9.79	4.51
Stockton, Kan.	Frank M. Jackson	922	Wheat Bran	17.22	3.44
do.	do.	923	Corn Chop	7.90	2.15
do.	do.	984	Shorts or Ship Stuff	18.80	3.65
Strawn, Kan.	Kuhlman Bros.	486	Corn Chop	8.57	3.63
Sylvia, Kan.	Sylvia Mill and Elevator Co.	233	Wheat Bran with Unground Screenings	14.19	4.67
do.	do. do.	234	Daisy Shorts	18.58	4.05
do.	do. do.	595	Corn Chop	9.10	4.16
Syracuse, Kan.	H. R. Taylor	393	do.	10.28	4.77

Syracuse, Kan.	H. R. Taylor	620	Bran (later mill run)	17.13	2.25
do.	L. P. Worden & Son	916	Corn Chop	9.45	4.03
Tampa, Kan.	Tampa Milling Co.	247	Wheat Bran	14.91	4.64
do.	do. do.	248	Wheat Shorts	16.70	5.12
do.	do. do.	249	Corn Chop	9.30	4.13
Tescott, Kan.	Stetson & Neely	908	do.	10.50	4.01
do.	do.	920	Bran	13.13	3.33
do.	do.	921	Shorts	18.47	4.18
Thayer, Kan.	Powell & Curry	822	Corn Chop	9.14	3.90
Tonganoxie, Kan.	Tonganoxie Milling Co.	575	do.	8.43	3.83
do.	do. do.	576	Shorts	16.85	4.75
do.	do. do.	577	Bran	14.28	4.22
Topeka, Kan.	Alfalfa Milling Co.	876	Pure Alfalfa Meal	15.55	1.65
do.	Geo. W. Barker & Onion	704	Mixed Feed	13.28	4.27
do.	do. do.	705	Corn Chop	9.19	4.11
do.	T. A. Beck	696	do.	9.03	4.25
do.	do.	697	Cracked Corn	8.56	3.86
do.	do.	698	Mixed Chop	9.27	4.29
do.	do.	699	Bran and Chop	13.63	4.24
do.	do.	1019	Beck's Chick Food	10.25	3.86
do.	D. O. Coe	759	Corn Chop	9.03	4.28
do.	do.	760	Mixed Chop	9.51	3.84
do.	do.	761	Mixed Feed	12.78	4.04
do.	do.	762	Mixed Chicken Feed	10.24	3.19
do.	do.	992	Chick-O	11.79	4.14
do.	Crosby Roller Milling Co.	647	White Shorts	17.54	4.38
do.	do. do.	648	Bran	16.45	4.57
do.	do. do.	649	Shorts	18.13	4.71
do.	Forbes Bros	792	Mixed Chop	9.03	4.15
do.	do.	793	Corn Chop	8.18	3.70
do.	do.	794	Corn Bran	6.21	4.30
do.	German Swine and Poultry Mercantile Co.	745	Eller's Highly Medicated Condiment Stock Food	19 70	4.38
do.	T. C. Kirkpatrick & Co.	881	Corn Chop	8.47	4.15
do.	Willis Norton & Co.	151	Wheat Bran	14.25	3.90
do.	do. do.	152	Wheat Shorts	16.52	4.89
do.	W. M. Hornbeck	808	Medicated Stock Salt for Farm Animals	....	......
do.	Kaw Milling Co.	846	Pure Wheat Shorts	16.73	4.00
do.	do.	847	Pure Wheat Bran	17.22	4.74
do.	Thos. Page	50	Bran	14.54	4.27
do.	do.	51	Shorts	15.63	4.51
do.	Shawnee Milling Co.	645	Bran	16.24	4.03
do.	do. do.	646	Shorts	18.12	4.89
do.	Topeka Milling Co.	205	Wheat Bran	15.29	4.85
do.	do. do.	206	Shorts	16.94	4.63
do.	Chas. Wolff Packing Co	988	Meat Meal	58.15	17.64
Toronto, Kan.	Zimmerman Seed Co.	340	Purity Baby Chick Food	9.03	3.27
Troy, Kan.	Sharits & Johnson	971	Corn Chop	8.77	4.10
do.	Clark Bros	162	Mixed Bran	12.86	6.64
do.	do.	163	Shorts	14.85 14.14	5.04 4.96

ANALYSES OF REGISTERED FEEDS—CONTINUED.

ADDRESS.	Manufacturer.	Registration No.	Feed.	Per cent. protein	Per cent. fat
Turon, Kan.	Turon Mill and Elevator Co.	334	Mixed Bran	14.77	5.33
do.	do. do.	335	Corn Chop	9.44	4.13
do.	do. do.	336	Shorts	12.33	2.14
Udall, Kan.	Udall Milling Co.	288	Corn Chop	8.40	3.49
do.	do.	289	Wheat Bran	14.37	4.22
do.	do.	290	Pure Wheat Shorts	15.06	4.47
Valley Falls, Kan.	Thos. Hatfield	153	Corn Chop	8.86	4.14
do.	Hauck Bros.	23	do.	9.46	4.27
Wa Keeney, Kan.	H. F. Osterkamp	692	do.	......	......
do.	do.	693	Mixed Horse and Cow Feed	......	......
do.	Ross & Waldo	933	Corn Chop	......	......
Wakefield, Kan.	W. H. Beatty	837	do.	8.90	3.76
do.	H. Niemoller & Sons	349	Wakefield Wheat Bran	14.11	4.16
do.	do.	350	Wakefield Shorts	14.83	4.40
do.	do.	351	Wakefield Corn Chop	9.21	4.51
Wamego, Kan.	Lord Milling Co.	614	Mixed Feed	15.68	5.38
do.	do.	615	Corn Chop	9.47	4.20
do.	do.	616	Shorts	19.71	4.73
do.	do.	617	Wheat Bran	16.80	3.80
Washington, Kan.	R. P. Brown	1039	Corn and Oats Chop	10.67	3.91
Wathena, Kan.	Fred Richards	458	Nuggett Mill Corn Chop	9.18	4.84
Waverly, Kan.	J. F. Grennon	775	Corn Chop	9.13	4.36
Weir City, Kan.	Weir City Milling Co	375	do.	8.41	4.19
Wellington, Kan.	Ætna Mill and Elevator Co	939	Shorts	20.15	5.54
do.	do. do.	940	Corn Chop	9.17	3.88
do.	do. do.	941	Bran	16.12	4.00
do.	Hunter Milling Co.	211	do.	15.52	4.22
do.	do.	212	Shorts	16.92	4.46
do.	do.	213	Corn Chop	8.34	3.70
do.	do.	245	Mill Run	15.72	4.60
do.	Wellington Mill and Elevator Co.	13	Bran	16.90	4.01
do.	do. do.	14	Rich Bran	18.10	4.41
do.	do. do.	15	Shorts	19.80	4.79
do.	do. do.	16	White Shorts	17.96 or 18.00	3.73
do.	do. do.	17	Chop	9.70	3.95
Wellsville, Agricola and Waverly, Kan.	Star Grain and Lumber Co.	323	Ear Corn Chop	7.28	3.26
do. do. do.	do. do.	324	Corn Chop	8.21	3.95

Westphalia, Kan.	V. Highberger	660	Corn Chop	8.03	3.87
White Cloud, Kan.	Jno. H. Lynds Mill and Elevator Co.	625	do.	8.05	3.17
do.	do. do. do.	626	Wheat Shorts	11.98	3.28
do.	do. do. do.	627	Wheat Bran	12.47	4.41
do.	White Cloud Milling and Elevator Co.	669	Wheat Shorts	15.21	4.24
do.	do. do. do.	670	Corn Chop	8.28	4.52
do.	do. do. do.	671	Wheat Bran	13.19	3.67
White Water, Kan.	White Water Milling and Elevator Co.	628	do.	16.03	4.53
do.	do. do. do.	629	Shorts or Middlings	16.79	4.24
Wichita, Kan.	East End Feed and Coal Co.	936	Corn Chop	8.95	3.51
do.	Hess Flour Co.	319	do.	10.29	4.27
do.	Howard Mills Co.	135	Peerless Princess Wheat Bran	16.95	4.88
do.	do.	136	Peerless Princess Shorts	14.47	3.82
do.	do.	137	Corn Chop	7.55	4.21
do.	do.	138	Corn Bran	8.22	6.05
do.	do.	267	Mixed Feed, Bran and Shorts	15.79	4.44
do.	Imboden Milling Co.	165	Wheat Bran	14.79	5.30
do.	do.	166	Ship Stuff	15.91	4.77
do.	do.	167	Corn Chops	8.91	3.95
do.	do.	168	Corn Bran	8.68	6.87
do.	F. M. Johnson	219	Corn Chop	8.70	4.08
do.	Kansas Milling Co.	239	Climax Wheat Bran	15.52	4.61
do.	do.	240	Corn Chops	8.36	3.25
do.	do.	241	Climax Special Wheat Feed or Shorts	13.95	3.48
do.	do.	790	Alfalfa Stock Food	12.78	3.77
do.	do.	791	Climax Wheat Shorts	17.49	4.08
do.	F. H. Kellogg	230	Chop and Bran	10.74	4.29
do.	do.	231	Corn Chop	8.53	4.11
do.	North End Coal and Feed Co.	325	do.	9.34	4.19
do.	Peerless Mills	220	Peerless Mills Corn Chop	7.92	3.78
do.	Poenisch Bros.	246	Banner Mills Corn Chop	9.13	3.97
do.	Puckett & Bagby	271	Corn Chop	9.44	4.23
do.	Red Star Mill and Elevator Co.	263	Wheat Bran, Wheat Screenings and Corn Bran	14.45	4.39
do.	do. do. do.	264	Wheat Shorts	17.54	5.63
do.	do. do. do.	265	Wheat White Shorts	17.05	4.62
do.	do. do. do.	266	Corn Chop	9.27	3.78
do.	Charles Seiner	210	do.	7.62	4.13
do.	Stevens Scott Grain Co.	189	Pure Corn Chop	8.50	3.17
do.	Watson Mill Co.	74	Wheat Bran	16.31	4.80
do.	do.	75	Wheat Shorts	15.77	3.89
do.	Weed & Abbott	236	Star Stock Food	14.49	4.02
do.	do.	237	Corn Chop	9.12	3.68
do.	Otto Weiss Alfalfa Stock Food Co.	1	Otto Weiss Alfalfa Stock Food	12.50	3.78
do.	do. do. do.	2	Otto Weiss Alfalfa Hog Food	17.95	4.26
do.	do. do. do.	3	Alfalfa Mash Every Day Egg Producer	17.90	3.34
do.	do. do. do.	4	Otto Weiss Chick Feed	11.02	2.76
do.	do. do. do.	5	Otto Weiss Hen Feed	10.59	3.88
do.	do. do. do.	6	Alfalfa Conditioner	18.09	13.28
do.	do. do. do.	7	Alfalfa Poultry Remedy	16.59	16.81
do.	do. do. do.	8	Alfalfa Hog Remedy	14.87	14.12

ANALYSES OF REGISTERED FEEDS—CONTINUED.

ADDRESS.	Manufacturer.	Registration No.	Feed.	Per cent. protein	Per cent. fat
Wichita, Kan.	**Otto Weiss Alfalfa Stock Food Co.**	262	**Otto Weiss Corn Chop**	8.90	3.82
do.	do. do.	633	**Kafir Shorts**	9.62	2.95
do.	**C. E. Weybright**	228	**Mixed Feed**	10.02	3.78
do.	do.	229	**Corn Chop**	8.74	4.15
do.	W. M. Wikoff	238	**Wikoff's Corn Chop**	9.71	3.78
Wilsey, Kan.	Robt. T. Ray Grain Co.	322	**Corn Chop**	8.99	3.81
Wilson, Kan.	W. L. Nesmith & Son	796	do.	9.42	3.95
do.	B. C. Paull	774	do.	......	......
Winfield, Kan.	Alexander Milling Co.	102	**Bran**	15.63	4.41
do.	do. do.	103	**Shorts**	16.68	4.91
do.	do. do.	104	**Bran and Shorts Mixed**	17.02	4.57
do.	do. do.	105	**Corn Chop**	9.60	4.26
do.	**Clarkson Milling Co.**	508	**Wheat Bran**	15.44	4.28
do.	do. do.	509	**Shorts**	17.08	4.36
do.	do. do.	510	**Corn Chop**	9.05	4.78
do.	**C. R. Peden**	959	do.	9.33	4.61
do.	**M. J. Phillips**	977	do.	9.47	3.50
do.	**Winfield Roller Mills**	60	**Bran**	15.08	3.94
do.	do. do.	61	**Shorts**	16.41	4.21
do.	do. do.	62	**Corn Chop**	9.19	4.89
Woodbine, Kan.	**Woodbine Mill and Elevator Co.**	947	**Bran**	16.08	3.65
do.	do. do.	948	**Shorts**	17.53	4.14
Yates Center, Kan.	**Yates Center Mills**	672	**Corn Chop**	8.91	3.94
do.	**Harder-Weide Hay and Grain Co.**	965	**Pure Corn Chop**	......	......
Shreveport, La.	**Caddo Cotton Oil Co.**	874	Caddo Cold Pressed Cotton **Seed Cake**	23.28	7.86
Minneapolis, Minn.	**International Stock Food Co.**	833	International Stock Food	11.96	5.76
do.	do. do.	832	International Poultry Food	16.75	3.79
do.	**Midland Linseed Co.**	438	Midland Brand, Old Process **Ground Linseed Cake.**	......	......
do.	do.	1026	Midland Old Process Ground **Linseed Meal**	33.48	6.95
do.	Security Remedy Co.	719	Security Stock Powder	......	......
do.	do.	720	Security Poultry Powder	......	......
do.	Stock Food Co. of America	1009	Clover Brand Stock Tonic	......	......
do.	do. do.	1010	Clover Brand Poultry Tonic	......	......
St. Paul, Minn.	Gold Coin Stock Food Co.	859	Gold Coin Stock Food	11.77	5.94
do.	Prussian Remedy Co.	806	Prussian Stock Tonic	12.90	3.91
Burlington Junction, Mo.	Perfect Stock Powder Co.	801	Perfect Stock Powder	0.58	0.08
Carthage, Mo.	Cowgill & Hill Milling Co.	320	Peacock Mixed Feed	15.27	4.85
do.	McDaniel Milling Co.	297	Mixed Feed	14.70	4.05

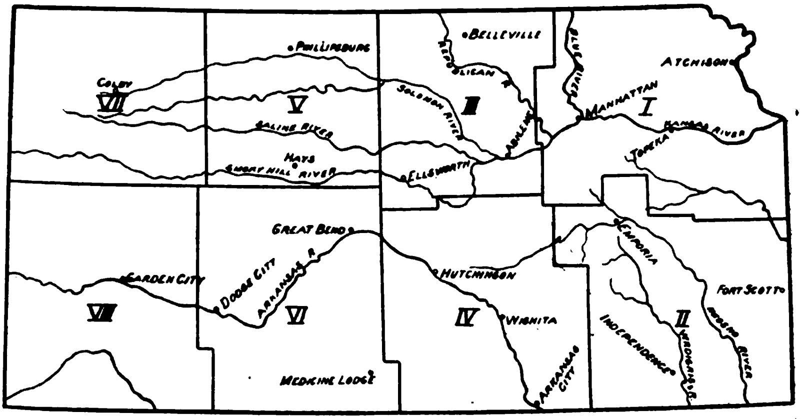
Joplin, Mo.	Brand-Dunwoody Milling Co.	831	"Dunwoody's Best" Mixed Feed	17.34	4.14
Kansas City, Mo	American Alfalfa Milling Co.	1015	"Alfalco" Horse and Mule Feed	13.20	3.61
do.	Arms & Kidder	292	Bran	14.25	4.30
do.	do.	293	Shorts	16.10	4.32
do.	H. G. Cherry	1014	Cherry's Alfalmo	10.67	0.85
do.	Fowler Commission Co.	183	Corn Chop	9.14	4.39
do.	K. C. Lead and Oil Works	423	Ground Oil Cake	34.66	7.19
do.	Pioneer Linseed and Lead Co.	684	Clark's Owl Brand Soft Pressed Oil Meal	31.50	10.75
do.	do. do.	731	Clark's Owl Brand Oil Meal	......	......
do.	F. E. Ransom & Co.	985	Corn Chop or Cracked Corn	9.40	4.37
do.	Russell Grain Co.	968	Russell's Corn Chop	9.98	4.82
do.	do.	1084	Ruslmo	......	......
do.	Southwestern Milling Co.	964	K. C. K. Bran	16.20	3.68
St. Joseph, Mo	Davis Milling Co.	419	Shorts	13.61	4.77
do.	do.	420	Bran	13.07	4.60
do.	do.	421	Corn Chop	8.14	4.24
St. Louis, Mo	Hunter Bros. Milling Co	782	Cottonseed Meal	46.33	7.48
do.	do. do.	783	Screened Cottonseed Cake	51.49	7.15
do.	Dr. L. D. LeGear Co	994	Dr. LeGear's Poultry Powder	......	......
do.	do.	995	Dr. LeGear's Stock Powder	......	......
do.	Ralston Purina Co.	442	Purina Mill Feed, Chick and Scratch Size	11.66	3.97
Tarkio, Mo.	Champion Feed Co.	966	Champion Feed	8.87	2.15
Beatrice, Neb	Black Bros.	399	Shorts	14.29	4.52
do.	do.	400	Bran	13.28	4.47
Bertrand, Neb.	R. H. Duff Co	735	Shorts	15.01	4.67
do.	do.	736	Bran	14.68	3.95
do.	do.	737	Corn Chop	9.68	4.10
Blue Springs, Neb.	Black Bros.	370	Bran	13.99	4.31
do.	do.	428	Black Bros. Shorts	11.33	3.55
Falls City, Neb	O. P. Heck	1007	Climax Chick Feed	11.27	2.90
Hardy, Neb	Jas. H. Fair	426	Shorts	7.56	4.41
do.	do.	427	Bran	12.11	5.07
Lincoln, Neb	Pinkerton Mfg. Co.	1017	Mrs. Pinkerton's Chick Food	11.53	1.95
Omaha, Neb., and Council Bluffs, Iowa	Alfalfa Meal Co.	858	Alfalmo	13.93	0.53
Omaha, Neb	Geo. H. Lee Co.	425	Lee's Egg Maker and Chick Grower	37.09	3.15
do.	M. C. Peters Mill Co.	824	Alfal-fat	11.48	0.63
do.	do. do.	825	Arab Horse Feed	10.91	3.95
do.	do. do.	826	June Pasture	10.70	1.56
do.	Rex Company	1013	Rex Conditioner	......	......
do.	J. L. Stalnaker Co	898	Great Western Conditioner	16.27	5.02
do.	Standard Stock Food Co	445	Standard Stock Food	13.30	7.16
do.	do. do.	446	Standard Poultry Food	13.29	1.58
do.	do. do.	447	Standard Milk Meal	29.06	3.53
Superior, Neb	Bossemeyer Bros.	777	Corn Chop	9.47	3.21
do.	Geo. Scoular	829	do.	......	......
Ashland, Ohio	Drs. Hess & Clark	814	Dr. Hess Stock Food	11.19	2.54
Cleveland, Ohio	G. E. Conkey Co.	1020	Conkey's Laying Tonic	......	......
Tiffin, Ohio	J. J. Fleck	1002	Fleck's Condition Powder	......	......
do.	do.	1003	Fleck's Stock Powder	......	......
do.	do.	1004	Fleck's Poultry Powder	......	......

ANALYSES OF REGISTERED FEEDS—CONCLUDED.

ADDRESS.	Manufacturer.	Registration No.	Feed.	Per cent. protein.	Per cent. fat.
Tiffin, Ohio	Seneca Company	1027	Seneca Poultry Powder		
do.	do.	1028	Seneca Stock Powder		
Alva, Okla	Alva Roller Mills	861	Shorts	16.07	3.51
do.	do.	862	Bran	17.79	4.38
Blackwell, Okla	Blackwell Milling and Elevator Co.	480	Shorts	18.79	4.36
do.	do. do.	481	Bran	16.48	4.52
Chandler, Okla	Chandler Cotton Oil Co.	818	Choice Cottonseed Meal		
do.	do.	819	Prime Cottonseed Meal		
Cherokee, Okla	Alfalfa Meal and Milling Co.	1011	Maz-a-Flora	12.75	2.61
Chickasha, Okla	Apache Cotton Oil and Manufacturing Co.	805	Choice Cottonseed Meal		
Guthrie, Okla	W. H. Coyle Co.	820	Prime Cottonseed Meal		
do.	Houghton & Douglass Cotton Co.	765	Choice Screen Cracked Cake		
do.	do. do.	766	Choice Meal	47.50	7.92
Muskogee, Okla	Muskogee Cotton Oil Co.	997	Cottonseed Meal	45.60	7.06
Norman, Okla	Norman Cotton Oil Mill Co.	788	"Prime" Oil Meal	50.67	8.58
Oklahoma City, Okla	Oklahoma Cotton Oil Co.	809	Prime Cottonseed Meal		
do. do.	do.	810	Prime Cottonseed Cracked Cake		
Shawnee, Okla	Shawnee Cotton Oil Co.	996	Prime Cottonseed Meal		
Philadelphia, Pa.	Pratt Food Co.	827	Pratt's Conditioner	12.49	5.54
do.	do.	828	Pratt's Food for Horses and Cattle	14.00	6.30
do.	do.	1112	Pratt's Poultry Regulator		
do.	do.	1080	Pratt's Animal Regulator		
Memphis, Tenn.	F. W. Brode & Co.	708	Owl Brand Cottonseed Meal		
do.	Humphreys-Goodwin & Co.	844	Dixie Brand Cottonseed Meal		
do.	do.	845	Dixie Brand Nut Cake		
Bartlett, Tex.	Bartlett Oil Mill	880	Texas Cold Pressed Cottonseed Cake	26.31	6.93
Burlington, Tex.	Texas Cooking Oil Co.	884	Cold Pressed Cottonseed Cake		
Mansfield, Tex.	Mansfield Cotton Oil Co.	815	Cottonseed Cake	26.64	8.75
Milwaukee, Wis.	Wilbur Stock Food Co.	861	Wilbur's Stock Food or Stock Tonic		

VARIATION IN COMPOSITION IN DIFFERENT REGIONS OF THE STATE.

As the work of analysis of the samples recorded on the foregoing pages proceeded, indications seemed to appear that there were differences in composition due to regional differences in origin. We have therefore collected together and averaged the results for the three feeds—bran, shorts and corn chop—as obtained on samples grouped into eight lots representing as many parts of the state. These eight regions are indicated on the accompanying map. While of approximately equal size they to a considerable extent also represent distinctly different drainage areas as well as progressive variation in climatic conditions.



Regions I and II are bounded on the west by the great belt of limestone hills which stretches across the state and marks the upper limit of the Carboniferous geological formation. Region I consists largely of the drainage basins of the Blue, Kansas and Marais des Cygnes rivers, while region II is characterized by those of the Neosho and Verdigris. Region III includes the lower stretches of the valleys of the Saline, Solomon, Republican and Smoky Hill rivers, while the waters of region IV flow almost wholly into the Arkansas, as do those of regions VI and VIII. Regions V and VII are in the higher altitudes drained by the Republican, Saline and Smoky Hill rivers. In regions III and IV we pass from the characteristics of eastern Kansas to those typical of the Great Plains, which are exemplified completely in regions V, VI, VII and VIII.

The average annual rainfall diminishes steadily from about forty inches per annum on the eastern border to less than fifteen inches at the Colorado line. The altitude ranges from about 690 feet, at Kansas City, Kan., to about 4000 feet.

The accompanying table exhibits the average results for the several regions and for the entire state. The numbers of samples coming from the different regions gives one a measure of the relative importance of each in respect to the staple crops, wheat and corn. Study of the figures shows a tendency to higher protein content as the place of origin is farther westward with all three of the feeds—bran, shorts and corn chop. The fat seems to be nearer constant, especially with corn. It is, of course, recognized that the grain milled in a given region is not all produced in that region, so that there must be some lack of sharpness, on this account, in such differences as exist. It should also be recognized that the moisture content probably diminishes as one goes westward, which would tend to increase the percentages of the other constituents.

AVERAGE PERCENTAGE OF PROTEIN AND FAT IN BRAN, SHORTS AND CORN CHOP FROM EIGHT REGIONS OF KANSAS, AND GENERAL AVERAGES FOR ALL.

REGION.	Bran.			Shorts.			Corn Chop.		
	No. of samples.	Percentage of protein.	Percentage of fat.	No. of samples.	Percentage of protein.	Percentage of fat.	No. of samples.	Percentage of protein.	Percentage of fat.
I.	32	14.57	4.35	31	15.46	4.11	79	8.76	4.03
II.	23	15.44	4.41	24	15.68	4.08	89	8.77	4.16
III.	30	15.34	4.16	32	16.20	4.22	41	9.50	4.03
IV.	59	15.59	4.25	60	16.73	4.46	83	9.23	4.05
V.	17	16.60	3.97	15	17.71	4.02	19	9.73	3.83
VI.	14	16.33	4.03	13	17.12	4.04	26	9.52	4.08
VII.	3	16.05	4.19	3	16.68	4.14	4	9.47	4.07
VIII.	1	17.13	4.25	......	....	......	9	9.70	4.25
Totals.	179	15.46	4.24	178	16.38	4.29	350	9.10	4.07

RULINGS UNDER THE LAW.

It is not possible with reference to any complicated business so to formulate a law that all circumstances and contingencies will be provided for. It becomes necessary, therefore, for the administrative officer charged with the enforcement of the law to adopt lines of action which the letter and the spirit of the law warrant, and at times to embody his judgment in definite rulings. In the administration of the feeding-stuffs law the Station officers have been guided by the interests of the consumer and the honest manufacturer as affected by the law, and have striven to incommode them as little as possible. The remainder of this Bulletin will be largely a discussion of the relation of the law to the several classes affected by it. Certain of its requirements are enlarged upon that there may be no doubt as to our attitude in the work of inspection. Some of these matters have been the subject of extended consideration by the attorney-general of the state, and it is believed that the views here presented are such as will stand the test of the courts.

OBJECTS OF THE LAW.

The law is calculated to benefit both the producer and the consumer of feeds coming within its scope. It benefits the consumer (1) by giving him an assurance concerning the nature of the article which he purchases; (2) by the statement of the net weight of the package; (3) by the guaranty of composition required, which is an index of the quality of the feed.

The manufacturer of feeds that are what they purport to be and that are sold in fair competition is benefited (1) by the elimination of adulterated and misbranded goods, which are by no means uncommon in the absence of a law of this kind; (2) by the elimination of the competition of short-weight packages; (3) by the advantage in the sale of high-grade goods resulting from a guaranty of the percentage of fat and of protein.

There are abundant and increasing evidences that feeds hitherto sold under the same name lack much of being identical. Under the name of bran, mixtures of very uncertain nature have been sold. Corn chop has not always meant the same thing, and with admittedly mixed feeds there has been still greater uncertainty.

In respect to weight, it is well known in some of our cities and towns that sacks of bran or chop supposed to be of 100 pounds' weight have been 5, 10 or 15 pounds short of that weight, to the disadvantage of the purchaser and of the competitor who puts out his feeds in full-weight sacks.

In respect to composition, by which is meant the chemical ingredients of the feed, such as fat, protein, carbohydrates and mineral constituents or ash, there are considerable differences in different brands of the same kind of feed. Thus cottonseed-meal is made in various grades, which differ greatly in value because of their difference in composition. The same thing is true of many other feeds.

SCOPE AND APPLICATION OF THE LAW.

It will be seen that section 1 defines concentrated feeding-stuffs for the purpose of the law, which definition agrees substantially with the ordinary use of the words, except that it does not include unmixed grains, either ground or whole. It might also be held that condimental feeds would not necessarily be so classed. To remove any doubt in this case the law specifically provides that they shall be sold in accordance with its provisions, and to prevent any evasion of the spirit of the law the various names under which this class of goods is sold are recited.

It will be seen that, in addition to condimental feeds, which are later referred to as condimental or medicinal stock foods, all mixed feeds, and all feeds which have been produced by altering in any way the composition of the original substance, must be held to be within the scope and application of the law. Hence, except as otherwise specifically provided, it applies to all by-products of seeds or grains, since in the manufacturing process to which the seed or grain is subjected certain parts are removed which, being different from the entire seed or grain in composition, leave a by-product that is also different from the original substance in composition. This would include bran, shorts and middlings, were they not especially excepted by the provisions of section 11.

The law applies to all kinds of mixed feeds. Many of the feeds as now put out by flouring-mills come within this classification, as they do not consist of pure bran or pure shorts, but of mixtures of these with each other or with wheat screenings, corn bran, etc. All such mixtures come within the scope of the law. Such mixtures, as well as all others, must be registered, and when sold carry the label provided for by section 4 of the law. It may also be mentioned that bran or shorts containing screenings or other admixtures will not be permitted by the federal authorities to enter interstate commerce under the names of the pure feeds.

REGISTRATION OF FEEDING-STUFFS.

The law requires that all concentrated feeding-stuffs, as defined in the law, excepting as specified in section 11, shall be registered by the director of the Experiment Station, but he is not required to register products that are misbranded or deleterious. To enable him to form a judgment on these points the law requires those applying for registration of feeding-stuffs to make certain statements concerning them. The ingredients used in preparing the feeding-stuff must be stated and the sources from which they are obtained. For example, if "mixed feed" is offered for registration the applicant must state what is mixed to make the feed. He might say "chop, bran and screenings." That would not be sufficient, as there are various kinds of chop, bran and screenings, and the specific kinds must be stated. Even in registering a single feed a statement of its origin is necessary. In brief, he must give the exact name which he expects to place upon the label, and he must state the kinds of grains, by-products or other materials which he incorporates in the feed, using their ordinary names. It is of the highest importance to the applicant that he make a truthful statement concerning his feeds, for if the later work of inspection shows that the article which he places upon the market does not agree with his statement concerning it, its registration will be revoked and he will be, moreover, liable to punishment for violation of the law.

The director will refuse registration if the name or brand under which it is proposed to sell the feed is false or misleading. This covers adulteration, as no mixed feed may be registered under the name of a single constituent, and the label under which the feed is sold must bear the registered name. If a mixture is sold for what it is there is no deception and no adulteration, but if such a mixture were sold under the name of only one of the components it would be a sale of adulterated feed. For example, a mixture of corn chop and corn bran may be sold as such if it is registered and is sold under the label and guaranty required by section 4, but if it is sold as corn chop the seller is liable to all the penalties of the law. Similar considerations apply to a mixture of wheat bran and corn bran, since the name bran when unqualified is universally taken to mean wheat bran. It must be registered and sold under some name that will show its character.

ANALYSIS OF SAMPLES.

The law is construed to require the Experiment Station to determine, without extra charge, the percentage of protein and of fat in registered feeds if the manufacturers desire it in order to make the guaranty required by section 4. If a more extended analysis is desired arrangements may be made with the chemist of the Station to have such work done. In such cases a charge is made, which is to be paid in advance. No analysis is begun on a feed offered for registration until the registration fee of ten dollars has been paid. Analyses are made in the order of registration if the samples are at hand.

Manufacturers are not infrequently disappointed in the results shown by the analysis of their samples. It is a matter of some difficulty to get a perfectly fair sample. To insure that justice be done manufacturers in our inspection work, the law prescribes the mode of sampling that is to be followed when samples for inspection are taken. It is apparent that manufacturers in taking samples upon which they are to base their guaranty should proceed with somewhat similar care, and a sample of not less than one or two pounds should be sent to the chemist by mail or prepaid express. All samples must bear the name and address of the sender as a means of identification.

Purchasers of feeds frequently suspect that they are not of the desired quality and request that analyses be made by the Experiment Station. While there is no provision in any of the laws requiring the Experiment Station or any other institution in the state to make such analyses without charge, it is our desire to serve the public interest, even to the extent of making analyses upon samples furnished by private individuals. It is seldom, however, that such samples serve any public interest and as a rule a charge must be made for such analyses. Those who wish analyses made should state specifically what constituents are to be determined, also the name and address of the dealer from whom the feed was obtained, the brand of the feed, and the quantity in the shipment. The value of the analysis will be very much increased by following the directions for sampling contained in the law.

In case of shipment of large amounts of feed coming within the scope of the feeding-stuffs law, which feed appears not to be as represented, it is sometimes possible to send a deputy inspector to examine and sample the feed. It must be understood that feed purchased outside the limits of the state and upon which the inspection tax has not been paid, and which has perhaps not even been registered, does not come within these provisions.

LABELING AND TAGGING.

The law provides that a distinct label or tag, as specified in section 4, must be on every package of concentrated feeding-stuff, as defined by the law, sold in the state. The guaranty as to the percentage of protein and fat required by the law is understood to be the minimum, and not necessarily the exact amount in the feed. The manufacturer guarantees that the percentages will be not less than those which he states. The label may be in the form of a tag attached to the package or the information may be printed upon the sack or other container, as suits the convenience of the manufacturer.

It is held that the label required by section 4 need not be attached to packages shipped to points outside the state unless the destination is near the Kansas line and the feed is likely to get back into Kansas markets.

Concerning sales of feed in bulk, the law is not clear in respect to the label described in section 4, and it is held that the delivery to the consumer of one such label with each lot purchased in bulk is in accordance with the spirit of the law, and that such delivery should be made. In respect to very small lots of ten pounds or less taken from a bulk lot in the store of a dealer, it is held that conspicuous display in connection with the bulk supply of a label giving the information required by section 4 is sufficient, and that a label need not be attached to the small lot.

Feeds subject to the inspection tax must, in addition to the tax tags required by the provisions of section 5, carry the label or tag provided for by section 4.

THE INSPECTION TAX.

Section 5 of the law provides for the payment of an inspection tax on certain kinds of feeds. This tax is to be collected by means of tags to be furnished by the director of the Experiment Station at the rate of 400 for five dollars. The law provides that all of the feeds named in section 5 shall pay this tax whether made in this state or not, and no matter by what means they are introduced. All such feeds sold or held for sale by any one within the state of Kansas must bear at least one tag on each package, and each 100 pounds or fraction thereof in a bulk lot must be accompanied by one tag. Residents of Kansas ordering any of these feeds for sale should insist upon it that the manufacturers ship the goods properly tagged to show that the inspection tax has been paid, and also labeled in accordance with section 4. The data required by section 4 may be printed on the back of the tax tag if desired. Counterfeiters of the tag, and users of counterfeit or fraudulent tags, will be punished to the full extent of the law. If dealers obtain feeds offered within the state or from other states that are not properly tagged it is their duty to see that tags are attached in accordance with the provisions of sections 4 and 5 in so far as they apply. Failure of a manufacturer or other dealer to attach the tags does not excuse any one else.

It would much facilitate the administration of the feeding-stuffs law if all manufacturers outside the state would attach the tax tags to all feeds requiring them which they ship into the state. We have, however, no hold upon them excepting through the specifications that may be made by dealers within the state, and all such dealers should, in securing quotations of prices, specify that any tax tags or labels required by the Kansas law be attached by the manufacturer. Dealers who do not do this cannot fail to be more or less under the suspicion of neglecting to attach proper tax tags and labels themselves before selling the goods within the state.

It is possible for a consumer to order feed from points outside the state and obtain it without any guaranty, tax tags or other conformation to the provisions of the Kansas feeding-stuffs law, and as long as he feeds it himself, offering none of it for sale and selling none, the transaction does not come within the scope of the Kansas law, being interstate commerce. On the other hand, the feeder relinquishes all protection that the law is designed to give. In cases in which the consumer purchases concentrated feeding-stuffs of dealers located in this state, the shipment of the feed direct from the jobber or manufacturer outside the state to the consumer without its passing through the warehouses of the dealer who sold the feed, does not relieve the feed from the required inspection tax, and dealers selling feed in that way without furnishing the consumer the necessary tax tags, or seeing that they are applied by the manufacturer, is violating the law.

MIXED FEEDS.

Mixed feeds have always been the medium through which the most flagrant frauds in the feeding-stuffs business have been perpetrated. Oat-hulls, rice bran, ground corn-cobs and other waste products of little or no feeding value have been systematically incorporated in such feeds. The value of mixed feeds cannot be estimated by a purchaser with much assurance of satisfactory results. In the case of pure feeds, the consumer can, to a degree, judge for himself, notwithstanding the considerable variations to which even they are subject in respect to composition and, consequently, feeding value. Mixed feeds have therefore always come under feeding-stuffs laws and have, indeed, received special attention.

The Kansas law requires that feeding-stuffs that have been subjected to any mixing process, or subjected to any process whereby the composition of the original material is altered, shall be registered with the director of the Experiment Station if sold, offered for sale or held for sale within the state of Kansas. It further provides that every sack or other package held for sale or sold within the state shall bear a distinct brand and conspicuous label in the English language, which shall state the name of the manufacturer or seller, the registered name, trade-mark or other designation of the feed, the net weight of the package, and a guaranty as to the percentage of fat and of protein.

It must be distinctly recognized that this provision has no bearing upon mixtures made for one for his own use, whether the user mixes the feed with his own hands, has it done by his hired man, or orders it done by a dealer. A consumer may, for his own use, order any mixture whatever made by a dealer, and the law has no application to the transaction. If he is feeding a ration to his animals he is thus able to modify it at any time and in any way that he sees fit. The law hampers him in no way whatever as long as the mixture made is not offered for sale.

While dealers are thus permitted to mix feeds in any way that may be wished by a purchaser upon his special order, he has no right to anticipate orders and mix feeds in advance, holding them in stock until purchased. Any mixture of feeds thus kept on hand by a dealer is subject to all of the provisions of the law as designated above.

Attention may be drawn to the fact that wheat bran mixed with wheat screenings, corn bran or other foreign substances must be regarded as a mixed feed, and its manufacturers are required to comply with the law as applied to mixed feeds. So, too, corn bran may not be mixed with corn chop without subjecting it to all of these provisions. The importance of bran and corn chop is such as to warrant special treatment. This is given in the succeeding paragraphs.

WHAT IS PURE BRAN?

In its present form the Kansas feeding-stuffs law requires no registration or special guaranty or tagging for pure bran or pure shorts, while impure feeds of the general nature of these must be registered as mixtures and be labeled so as to show the net weight of the package, the name and address of the manufacturer, the name of the feed, and a guaranty as to the percentage of fat and of protein. Hence a definition or description of pure bran becomes of considerable importance to manufacturers and consumers alike.

The chemist of the Experiment Station, who is by the law charged with the duty of inspecting feeding-stuffs in person or by deputy, holds that bran to be pure must not include anything that is separated from the wheat in preparing it for the milling process. Some wheat as marketed contains bits of straw, broken weed stems, oats, cheat and other foreign substances that must be removed before the wheat enters the rolls for grinding. All such screenings must be excluded if the bran is to be classed as pure.

The shrunken wheat unfit for flour-making and also removed in this preparatory process is doubtless of equal feeding value with the bran, and its presence in bran is not economically objectionable, though technically an impurity. This shrunken wheat is by some millers ground and separated into a coarse part and a fine part, the former being put into the bran and the latter into the shorts. Such action is held to be legitimate, but this should not be taken as an approval of the introduction in a ground state of the other light materials of little feeding value. If such materials, either ground or unground, are marketed with the bran the product must be sold as "bran and screenings," and under the general label and guaranty referred to, and must be registered with the director of the Experiment Station.

Some millers who make corn-meal dispose of the corn bran separated in that process by mixing it with the wheat bran. This practice is not legitimate, and if followed the mixture must be designated as "wheat bran and corn bran" and be registered and labeled as described above.

Millers can adopt and maintain a high standard for their bran, and put out a product in which they can take pride, only by keeping out all adulterations. These by-products of questionable character can be disposed of without loss by making a mixed feed with which they may be incorporated, which must of course be registered with the director of the Experiment Station annually and carry the proper label and guaranty. Purchasers will then know what they are getting, and Kansas bran will be of a uniformly high grade.

Attention may also be drawn to the fact that the rulings above stated are in harmony with the policy of the federal authorities in respect to mill products entering interstate commerce.

ADULTERATED CORN CHOP.

Under the Kansas feeding-stuffs law pure corn chop is not subject to registration or tagging, but is subject to inspection in respect to purity and weight of packages. The law provides that all weights of feeding-stuffs shall be net; that is, a sack of corn chop purporting to be 100 pounds must weigh enough more to make up for the weight of the sack. Reasonable allowance should be made for atmospheric influences.

Pure corn chop is the product obtained by grinding well-cleaned shelled corn, removing nothing therefrom and adding nothing thereto. Anything resembling corn chop but not meeting the preceding definition must be treated either as a mixed feed or as one which has been subjected to a "process whereby the composition of the original material is altered." In either of these two cases the product must be registered annually with the director of the Experiment Station and be labeled so as to show the name and address of the manufacturer, the true nature of the feed, the net weight, and the percentage of protein and of fat guaranteed.

In the manufacture of corn-meal the corn bran is removed by bolting, and the temptation is strong upon a miller to put this by-product in with his corn chop. This practice, as indicated above, is not legitimate, constituting in fact a serious adulteration. Corn bran, though possessing a good percentage of fat and of protein, is greatly inferior to whole corn in its content of starch and has a high per cent. of fiber which is of little or no net feeding value. If a manufacturer wishes to work off his corn bran with corn chop he must plainly tag it as "corn chop and corn bran" and sell it under all the conditions applying to mixed feeds.

So, too, if the miller after grinding corn removes some of the finest and best parts for corn-meal and sells the remainder as corn chop he is violating the law unless he sells it under a label that shows its true nature, and has complied otherwise with all of the provisions of the feeding-stuffs law.

Again, corn chop is not to be made the medium through which screenings of various kinds are disposed of, neither is it to include rotten corn, corn-cobs or dirt. There is no question that in the past much of such fraudulent feed has been foisted upon the public, and it is against such that the law operates.

CONDIMENTAL OR MEDICINAL STOCK FOODS.

The attention of druggists, and perhaps others who do not handle ordinary concentrated feeding-stuffs, is especially directed to the provision of the law in respect to condimental or medicinal stock foods. Condimental or medicinal stock foods and condimental feeds are held to be articles containing condimental or medicinal substances, or both condimental and medicinal substances, the product being recommended and sold for use with the ordinary feed of animals in the usual condition of health with the object of increasing the production of milk or eggs or increasing the growth or rate of fattening of animals, or of otherwise contributing to the nutrition of animals. The sale of any article agreeing with the preceding definition is contrary to the law unless the same has been properly registered with the director of the Experiment Station and is labeled in accordance with the law. To remove all uncertainty concerning the application of the law to this general class of goods the law specifically enumerates a great variety of the names under which they are sold. Druggists can protect themselves only by refusing to handle unregistered condimental feeds. There is an abundant variety of such preparations already registered.

There is little doubt that large quantities of condimental stock foods are used each year without any adequate financial return to the feeder. Tests made by several experiment stations have shown that with animals in the ordinary condition of health there is little or no difference in the results obtained in feeding, whether condimental stock foods are used in addition to the regular ration or not. Furthermore, it now and then comes to notice that farmers are defrauded through the purchase of materials that are purely medicinal according to the claims of the makers but the use of which is no real advantage. It would seem to be the part of wisdom not to administer medicines or medicinal preparations to animals in a healthy condition, and when they are in ill health to secure competent advice and treat them for the special difficulty found to be present.

RESPONSIBILITY OF DEALERS.

The attention of dealers in feeds subject to registration and taxation, who are not manufacturers of them, is drawn to the fact that if they sell such feed that has not been registered and tagged in accordance with sections 4 and 5 of the law they are violating the law, even if it was sold them by a manufacturer in this state who had neglected to tag it. Dealers should refuse to accept shipments of feed not properly tagged, unless they are willing to go to the expense of registering and tagging it themselves. There is no lack of registered feed on the market. A dealer who hires his feed prepared for him, instead of purchasing it, is, before the law, the manufacturer of the feed, and it is his duty to have the feed registered and see that it is properly tagged before selling it, if it is a feed requiring such registration and tagging.

It is human nature for every one to attempt to push responsibility for wrong-doing back upon some one else, but in the case of a sale of feeding-stuffs it cannot be too strongly insisted that each one who makes a sale in which the requirements of the law have not been fully complied with is guilty of its violation, regardless of the number of times that the law may have been violated by others in preceding sales of the same feed. Violations of the law by another are no excuse for any one. Dealers and consumers alike are invited to bring to the attention of the Experiment Station officers any transactions or conditions that indicate violation of the law, and they will be investigated and action taken in accordance with the fundamental principle that the object of the law is to protect consumers and honest dealers and manufacturers from the impositions and unfair competition of the unscrupulous.

SUMMARY.

The Bulletin begins with a summary of the history of the feeding-stuffs law and its administration, followed by the amended law in full.

The inspection work and analyses made under the amended law then follow. The analyses of inspection samples show that in general the feeds were fairly up to the guaranties. The most of the deficiencies were with corn chop, upon which a guaranty is no longer required.

The analyses of registration samples present an interesting and valuable compilation of data concerning Kansas feeds. These are given some general study in reference to the region of the state in which the feed was produced. From this it appears that the protein content tends to become higher the farther west the feed originates.

The remainder of the Bulletin is devoted to an exposition and explanation of the requirements of the law and to rulings made under it.

THE FOLLOWING BULLETINS

ARE AVAILABLE FOR DISTRIBUTION TO THOSE RESIDENTS OF KANSAS WHO MAY DESIRE THEM:

No. 12....Preliminary Experiments with Fungicides for Stinking Smut of Wheat.
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No. 15....Additional Experiments and Observations on Oat Smut.
No. 16....Experiments with Sorghum and with Sugar Beets.
No. 43....Experiments with Sorghum and with Sugar Beets.
No. 52....Kansas Weeds—Preliminary Circular on Distribution.
No. 120....Tests of Forest Trees.
No. 121....Treatment and Utilization of Flood-damaged Lands.
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No. 129....Kansas Mammals in their Relation to Agriculture.
No. 135....Grading Cream.
No. 136....Press Bulletins Nos. 125-151.
No. 137....Variations in the Test of Separator Cream.
No. 138....Effect of Bacteria in Wash-water of Butter.
No. 139....The Study of Corn.
No. 140....Milking Machines.
No. 141....Commercial Seeds of Brome-grass and of English and Kentucky Blue-grasses: Adulterants and Substitutes and their Detection.
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No. 151....Alfalfa Breeding.
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No. 153....Deterioration of Red Texas Oats in Kansas.
No. 154....The Mound-building Prairie Ant.
No. 155....Alfalfa.

The Bulletins of the Experiment Station are sent free to applicants. Farmers are invited to send the names of others who would value them and samples will be sent, with return cards upon which applications for future issues may be made.

Address: DIRECTOR EXPERIMENT STATION,
Manhattan, Kan.

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Kansas State Agricultural College.

Bulletin No. 159—March, 1909.

Chemistry Department.

Analyses of Eggs.

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Experiment Station
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Manhattan.

Bulletin No. 159—March, 1909.
Chemistry Department.

J. T. WILLARD, D. Sc., Chemist.
R. H. SHAW, B. S., Assistant Chemist.

Analyses of Eggs.

IN the summer of 1905 the Animal Husbandry Department, under which at that time the poultry experiments were conducted, had in progress a test of the egg-producing capacity of representative hens from six pure breeds of chickens. This situation afforded a favorable opportunity for making some investigations concerning the physical and chemical characteristics of the eggs. The plans for these were chiefly the outgrowth of consultation between Professor Erf and Mr. Shaw. At that time it was expected that a bulletin would be issued concerning the egg-laying test in all its details, and it was planned to publish the chemical results as a part of this Bulletin. The publication of the data concerning the feeding and egg-production has been abandoned excepting in so far as it has already been given in press bulletins. The chemical investigations have involved the expenditure of a large amount of time, and though less interesting without the matter which it had been expected would accompany them the results are presented in detail in this Bulletin.

Though seven breeds of chickens were on trial in respect to egg-production, only four were used in the chemical tests. These were American Reds owned by J. Martin, Wichita, Kan.; Barred Plymouth Rocks owned by Mrs. J. W. Jones, Abilene, Kan.; Single Comb White Leghorns owned by the Agricultural

College, and White Wyandottes owned by Beecher & Beecher, Belleville, Kan. The Plymouth Rocks were hens, while the other breeds were pullets, of which the American Reds were the best matured at the beginning of the test, November 1, 1904. As the eggs for analysis were collected in June and July, 1905, all were well matured by that time. All of the eggs were laid within the six weeks between June 18 and July 31, 1905.

Measurements were made of both diameters of each egg, and of the thickness and strength of the shell. The diameters were measured to tenths of millimeters by means of calipers, and the thickness of the shell was measured to ten-thousandths of an inch by a micrometer caliper. The shell was measured in three places, usually the two ends and a side, and the average of the three taken. The strength of the shell was ascertained in terms of the weight necessary to perforate it, which was ascertained by a specially devised machine. The weight of each egg was taken, and also of the white, yolk and shell separately, from which the percentages of these three parts were calculated.

The analyses that were made of each egg were limited to determinations of water in the white, and of water, ether extract and ash in the yolk. The total solids of the white were taken to be protein, the percentage of other constituents being extremely small, and the protein of the yolk was also calculated by difference. All of the eggs laid within the six weeks were thus measured and analyzed. From the analytical results thus obtained with the white and yolk separately, the percentages of protein, fat and water in the whole egg were calculated.

In addition to the analyses above indicated, determinations of phosphorus were made in composite samples taken from the yolks of the egg laid by each hen for each of the six weeks; that is, with each hen the eggs laid for one week were sampled for a composite sample in which phosphorus was determined, and the eggs laid the next week were similarly sampled for another determination, etc. In some cases no eggs would be laid within a week, and hence there was no sample.

In the first forty-nine analyses the weight of the egg after boiling was taken as the basis upon which the percentages of white and of yolk were calculated, and the weight of the shell was not taken. In the remainder of the analyses the shell, white and yolk of each egg were weighed separately and their sum taken as the weight of the egg upon which calculations are based. As samples dried somewhat during weighing the weight of the cooked egg was slightly greater than that of the sum of the observed weights of the three parts.

The estimation of ash in the yolk was made by igniting the dry substance in a flat porcelain dish in a muffle-furnace.

The ether extract was obtained by extracting the perfectly dry yolk with anhydrous ether. While consisting chiefly of fat, it also included lecithin.

At this point it may be stated that Mr. Shaw resigned his position with this Experiment Station and went to the Nebraska Station January 1, 1906, a large proportion of the analyses of the eggs being yet uncompleted. By the courtesy of the Nebraska Experiment Station arrangements were made by which a large number of determinations of ether extract were made in its chemical laboratory for us by Miss Stella Hartzell, under the supervision of Mr. Shaw, and grateful acknowledgment for this courtesy is hereby made.

The following tables show the details of the results upon each egg. It will be impossible to discuss all of these observations, and they are presented here in this extended way in order that students of the subject may be able to utilize the data in full in respect to any questions upon which they have application. Following the detailed tables are some general comments upon the results, also a table of averages.

AMERICAN RED No. 3.

DATE. 1905.	Analysis No..	Laboratory No..........	No. of egg....	Long diameter of egg...	Short diameter of egg...	Weight to perforate shell.	Av. thickness of shell, in inches	Wt. of egg, in ounces...	Percentage of white.......	Percentage of yolk.........	Percentage of shell........	Percentage of protein in white.......	Percentage of water in white.......	Percentage of protein in yolk.........	Percentage of ether extract in yolk.	Percentage of water in yolk.........	Percentage of ash in yolk..	Percentage of protein in egg.........	Percentage of ether extract in egg.	Percentage of water in egg.........
Jun. 22..	64	1063	1	2.36	1.67	4.52	0.0133	2.04	56.62	33.25	8.43	10.33	89.62	17.14	33.57	47.76	1.53	11.59	11.16	66.68
" 23..	79	1078	2	2.32	1.65	5.24	0.0162	1.96	56.65	33.01	10.35	10.18	89.42	15.89	34.13	47.76	1.62	10.95	11.47	66.67
" 26..	121	1120	3	2.36	1.63	4.78	0.0124	1.92	55.51	36.13	8.26	10.96	89.04	16.14	34.08	48.29	1.49	11.94	12.31	67.05
" 27..	136	1135	4	2.30	1.67	3.96	0.0139	1.96	57.50	32.91	9.58	12.08	87.92	16.07	34.27	48.00	1.66	12.23	11.27	66.88
" 30..	183	1182	5	2.39	1.63	....	0.0137	2.02	56.85	34.49	8.65	10.72	89.28	15.17	30.16	53.20	1.47	11.32	10.40	69.12
Jul. 1..	198	1197	6	2.20	1.62	5.98	0.0139	1.80	55.29	34.65	10.07	11.72	88.28	17.14	33.73	47.68	1.45	12.41	11.69	65.80
" 3..	230	1229	7	2.36	1.63	5.00	0.0141	1.91	55.40	34.78	9.83	11.24	88.76	15.92	33.67	48.88	1.58	11.76	11.71	66.15
" 4..	245	1244	8	2.29	1.65	3.78	0.0143	2.00	57.14	33.90	8.96	9.97	90.03	16.54	33.58	48.49	1.49	11.31	11.39	67.91
" 5..	258	1257	9	2.24	1.62	3.96	0.0120	1.85	59.26	34.24	8.35	10.42	89.58	16.79	34.35	47.47	1.39	11.81	11.76	69.36
" 6..	267	1266	10	2.22	1.57	2.84	0.0136	1.70	54.25	36.31	9.39	....	....	17.24	34.02	47.13	1.61	....	12.35	....
" 8..	285	1284	11	2.35	1.67	6.47	0.0136	2.08	58.05	32.73	9.02	9.93	90.07	17.07	34.40	47.09	1.44	11.32	11.58	67.64
" 10..	303	1302	12	2.26	1.62	7.19	0.0115	1.84	57.25	34.28	8.46	11.61	88.39	18.83	31.84	47.76	1.57	13.09	10.92	66.98
" 12..	323	1322	13	2.36	1.66	6.49	0.0132	1.93	58.88	31.90	9.21	10.27	89.73	18.28	35.45	44.58	1.69	11.87	11.30	67.08
" 13..	333	1332	14	2.28	1.63	3.84	0.0123	1.98	57.75	33.24	9.01	10.46	89.54	16.89	34.40	47.08	1.63	11.66	11.44	67.41
" 14..	339	1338	15	2.21	1.66	....	0.0133	1.86	57.88	33.19	8.92	10.18	89.82	16.75	33.52	48.17	1.56	11.45	11.12	67.97
" 17..	262	1361	16	2.33	1.62	4.92	0.0112	1.90	57.06	34.77	8.18	10.65	89.35	16.84	33.00	48.61	1.54	11.92	11.38	67.87
" 18..	371	1370	17	2 2.	1.61	7.01	0.0140	1.86	56.70	35.58	9.59	10.67	89.33	17.71	35.30	45.83	1.66	12.35	12.55	66.77
" 21..	406	1405	18	2.31	1.62	7.37	0.0125	1.89	56.45	34.62	8.89	10.92	89.08	16.80	33.47	48.14	1.59	11.98	11.58	66.95
" 22..	417	1416	19	2.31	1.65	5.80	0.0130	1.95	58.44	32.26	9.30	9.92	90.28	16.43	34.85	46.98	1.74	10.98	11.24	67.96
" 23..	430	1429	20	2.03	1.59	4.59	0.0123	1.72	54.68	36.22	9.11	11.10	88.90	16.10	33.95	48.42	1.53	11.90	12.30	66.14
" 25..	452	1451	21	2.30	1.66	5.91	0.0147	1.99	57.46	32.16	10.23	10.03	89.97	16.53	34.70	47.50	1.77	11.03	11.00	66.92
" 26..	464	1463	22	2.21	1.63	7.38	0.0137	1.85	57.25	32.63	10.12	9.99	90.01	17.01	33.95	47.42	1.62	11.28	11.08	67.08
" 28..	486	1485	23	2.32	1.63	5.62	0.0135	1.94	57.86	31.96	10.17	9.93	90.07	17.63	32.60	48.07	1.70	11.41	10.43	67.55
" 29..	498	1497	24	2.25	1.64	5.18	0.0134	1.85	56.30	33.83	9.87	10.57	89.43	16.67	33.83	47.86	1.59	11.59	11.47	66.60
Totals........................				......	......	124.94	0.3196	45.80	1366.61	818.04	222.45	243.70	2055.90	403.58	810.37	1147.60	37.92	275.20	274.90	1545.54
Averages......................				2.285	1.64	5.95	0.0133	1.908	56.94	33.87	9.268	10.6	89.39	16.816	33.76	47.817	1.58	11.965	11.45	67.197

AMERICAN RED No. 6.

DATE. 1905.	Analysis No.	Laboratory No.	No. of egg.	Long diameter of egg.	Short diameter of egg.	Weight to perforate shell.	Av. thickness of shell, in inches.	Wt. of egg, in ounces.	Percentage of white.	Percentage of yolk.	Percentage of shell.	Percentage of protein in white.	Percentage of water in white.	Percentage of protein in yolk.	Percentage of ether extract in yolk.	Percentage of water in yolk.	Percentage of ash in yolk.	Percentage of protein in egg.	Percentage of ether extract in egg.	Percentage of water in egg.
Jun. 23..	80	1079	1	2.21	1.67	3.85	0.0131	1.91	56.45	34.43	9.11	12.78	87.22	16.68	34.80	47.04	1.65	12.95	11.98	65.42
" 30..	184	1183	2	2.23	1.66	6.06	0.0138	1.96	56.65	34.41	8.96	10.81	89.19	17.51	33.04	47.79	1.66	12.16	11.37	67.95
Jul. 1..	199	1198	3	2.18	1.62	6.08	0.0150	1.79	40.23	48.87	10.91	10.57	89.93	15.09	23.12	60.45	1.34	11.62	11.29	65.50
" 3..	281	1230	4	2.32	1.62	7.55	0.0138	.91	53.39	36.86	9.72	11.37	88.63	16.54	31.39	50.66	1.41	12.16	11.57	65.94
" 22..	418	1417	5	2.18	1.63	6.52	0.0118*	1.87	59.06	32.98	8.44	12.52	87.48	15.48	33.35	49.93	1.73	12.50	10.33	68.00
" 24..	440	1439	6	2.12	1.62	....	0.0131	1.76	56.28	34.99	8.75	12.10	87.90	17.92	31.91	48.62	1.58	13.07	11.14	66.50
" 25..	453	1452	7	2.18	1.62	8.35	0.0137	1.77	53.16	36.76	10.07	11.47	88.53	17.52	32.00	48.33	1.645	12.53	11.75	64.99
" 26..	465	1464	8	2.15	1.62	5.88	0.0138	1.75	53.10	36.64	10.27	10.79	89.21	17.65	31.90	48.71	1.74	12.20	11.70	65.24
" 27..	477	1476	9	2.21	1.62	....	0.0134	......	....	....	....	....	....	....	....	....	......	....	....	....
" 28..	487	1486	10	2.10	1.62	9.35	0.0131	1.67	52.60	37.36	10.04	10.26	89.74	17.90	32.88	48.56	1.66	12.07	12.27	65.34
" 29..	499	1498	11	2.13	1.75	6.42	0.0145	1.61	53.37	35.06	11.55	10.87	89.18	16.88	32.80	48.56	1.76	11.71	11.50	64.58
Totals..............				.....	.....	60.06	0.1486	18.00	534.29	363.86	97.82	113.48	886.46	169.17	317.19	498.65	16.19	122.97	114.90	659.46
Averages............				2.182	1.64	6.67	0.0135	1.80	53.429	36.386	9.78	11.348	88.646	16.917	31.719	49.865	1.619	12.297	11.49	65.946

AMERICAN RED No. 214.

Date. 1905.	Analysis No.	Laboratory No.	No. of egg	Long diameter of egg	Short diameter of egg	Weight to perforate shell.	Av. thickness of shell, in inches	Wt. of egg, in ounces	Percentage of white	Percentage of yolk	Percentage of shell	Percentage of protein in white	Percentage of water in white	Percentage of protein in yolk	Percentage of ether extract in yolk.	Percentage of water in yolk	Percentage of ash in yolk.	Percentage of protein in egg	Percentage of ether extract in egg.	Percentage of water in egg
Jun. 19..	24	1023	1	......	......	....	0.0154	1.89	57.12	32.21	....	11.84	88.16	17.95	30.68	50.08	1.51	12.54	9.88	66.50
" 21..	48	1047	2	2.23	1.60	7.88	0.0143	1.82	58.56	33.57	....	13.00	87.00	16.71	32.07	49.77	1.46	12.55	10.73	63.29
" 22..	65	1064	3	2.17	1.58	3.84	0.0156	1.73	57.08	32.68	10.28	11.67	88.33	16.95	31.24	49.73	2.08	12.19	10.21	66.64
" 24..	94	1093	4	2.24	1.58	....	0.0142	1.78	56.04	32.11	11.85	12.70	87.30	17.70	31.62	49.23	1.45	12.80	10.16	64.76
" 26..	122	1121	5	2.23	1.59	7.58	0.0139	1.76	58.16	31.69	10.16	12.76	87.24	17.12	32.32	49.17	1.39	12.83	10.24	66.27
" 28..	150	1149	6	2.28	1.63	6.80	0.0132	1.87	55.90	34.00	10.09	12.48	87.52	17.47	32.41	48.66	1.46	12.91	11 04	65.46
" 29..	168	1167	7	2.12	1.58	6.42	0.0149	1.69	56.56	32.71	10.71	12.74	87.26	15.94	33.84	48.66	1.56	12.39	11.07	65.26
" 30..	185	1184	8	2.14	1.58	5.64	0.0141	1.69	54.64	34.64	10.72	12.32	87.68	17.41	31.48	49.61	1.50	12.77	10.90	65.08
Jul. 2..	214	1213	9	2.25	1.62	5.88	0.0133	1.89	57.91	32.21	10.49	12.90	87.10	17.21	32.18	49.01	1.60	13.03	10.36	65 71
" 3..	232	1231	10	2.14	1.60	8.24	0.0145	1.73	54.16	34.15	11.69	13.16	86.84	16.31	31.87	50.27	1.55	12.69	10.88	64.78
" 4..	246	1245	11	2.31	1.54	5.30	0.0145	1.78	57.49	31.87	10.64	12.08	87.92	17.79	31.67	48.99	1.55	12.62	10.09	66.22
" 6..	268	1267	12	2.19	1.58	5.39	0 0141	1.74	55.76	33.81	10.45	12.60	87.40	18.05	31.51	48.95	1.61	13.12	10.65	65.23
" 7..	277	1276	13	2.13	1.57	.....	0.0137	1.67	55.84	33.88	10.30	12.50	87.50	18.34	31.91	48.57	1.34	13.18	10.77	65.30
" 8..	286	1285	14	2.08	1.59	6.48	0.0146	1.69	56.70	32.55	10.83	11.92	88.08	17.63	37.55	48.46	1.36	12.49	10.58	65.78
" 10..	304	1303	15	2.25	1.57	5.34	0.0132	1.81	50.32	31.28	8.40	14.51	85.39	18.67	31.02	48.82	1.59	14.62	9.71	66.76
" 11..	314	1312	16	2.11	1.56	6.29	0.0133	1.63	57.24	31.56	11.19	12.22	87.78	17.96	31.50	49.00	1.585	12.65	9.935	65.70
" 13..	334	1333	17	2.27	1.59	6.49	0.0128	1.79	57.49	32.48	10.02	12.46	87.54	17.64	31.81	49.19	1.36	12.99	10.35	66.31
" 15..	350	1349	18	2.23	1.60	7.96	0.0139	1.79	57.66	31.83	10.57	13.24	86.76	17.39	32.64	48.46	1.51	13.17	10.41	65.46
" 16..	356	1355	19	2.19	1.59	7.80	0.0136	1.77	56.97	32.46	10.58	12.46	87.54	17.13	32.15	49.26	1.455	12.66	10.45	65.88
" 18..	372	1371	20	2.23	1.58	7.07	0.0136	1.77	57.77	32.07	10.15	12.64	87.36	17.58	31.78	49.10	1.585	12.92	10.18	66.18
" 19..	381	1380	21	2.20	1.60	5.87	0.0142	1.78	56.45	32.60	10.75	12.20	87.80	17.98	32.25	48.83	1.49	12.75	10.52	65.33
" 21..	407	1406	22	2.22	1.60	6.18	0.0139	1.79	57.36	32.17	10.48	12.51	87.42	18.19	31.18	49.20	1.48	13.05	10.02	65.99
" 22..	419	1418	23	2.15	1.61	....	0.0131	1.73	60.13	29.70	10.17	11.74	88.26	17.44	32.55	48.82	1.69	12.24	9.68	67.45
" 24..	441	1440	24	2.17	1.60	6 84	0.0147	1.76	59.07	30.27	10.68	12.54	87.46	17.89	31.60	48.72	1.69	12.82	9.57	66.47
" 25..	454	1453	25	2.11	1.58	7.86	0.0134	1.64	58.26	31.07	10.66	....	.....	17.46	31.90	49.10	1.54	....	9.92	....
Totals........				......	.....	136.60	0.3500	43.99	1425.49	809.62	241.86	301.36	2098.64	437.24	797.58	1226.55	38.29	307.88	258.81	1577.21
Averages........				2 105	1.525	6.5	0.0140	1.76	57.02	32.38	10.516	12.556	87.44	17.49	31.90	49.06	1.53	12.83	10.33	65.717

AMERICAN RED No. 218.

Date. 1905.	Analysis No..	Laboratory No..........	No. of egg....	Long diameter of egg...	Short diameter of egg...	Weight to perforate shell.	Av. thickness of shell, in inches......	Wt. of egg, in ounces...	Percentage of white.......	Percentage of yolk.........	Percentage of shell.......	Percentage of protein in white.......	Percentage of water in white.......	Percentage of protein in yolk.........	Percentage of ether extract in yolk.	Percentage of water in yolk.........	Percentage of ash in yolk..	Percentage of protein in egg.........	Percentage of ether extract in egg.	Percentage of water in egg.........
Jun. 18..	11	1010	1	2.37	1.71	....	....	2.19	59.29	31.12	....	12.88	87.62	18.86	35.01	44.82	1.81	13.19	10.87	65.80
“ 20..	35	1034	2	2.27	1.69	6.55	0.0124	2.12	57.10	33.11	....	12.52	87.48	17.18	34.04	47.13	1.65	12.83	11.37	66.56
“ 21..	49	1048	3	2.26	1.66	....	0.0125	1.97	54.61	34.13	....	13.30	86.70	16.23	34.72	47.47	1.53	12.79	11.71	63.54
“ 22..	66	1065	4	2.28	1.65	4.42	0.0118	1.91	56.79	34.85	8.35	12.62	87.88	19.09	30.86	48.49	1.61	13.80	12.25	66.51
“ 25..	105	1104	5	2.30	1.72	5.46	0.0130	2.08	57.44	33.97	8.57	13.02	86.98	16.82	32.99	49.26	1.43	13.01	11.20	66.70
“ 26..	123	1123	6	2.34	2.08	4.32	0.0129	2.04	57.15	34.04	8.82	13.62	86.38	16.46	34.68	47.42	1.44	13.37	11.80	65.50
“ 28..	151	1150	7	2.20	1.67	3.87	0.0149	1.89	59.06	30.68	10.31	14.81	85.19	17.16	33.20	48.26	1.38	14.01	10.17	65.18
“ 30..	186	1185	8	2.28	1.70	....	0.0130	2.09	60.73	30.89	8.38	12.98	87.02	17.59	33.39	47.41	1.61	13.32	10.81	67.52
Jul. 1..	200	1199	9	2.24	1.66	3.40	0.0121	1.88	58.20	32.75	9.04	14.45	85.55	17.59	33.67	47.35	1.39	14.16	11.05	65.20
“ 2..	215	1214	10	2.24	1.65	5.44	0.0121	1.95	54.56	31.45	8.70	12.60	87.40	17 10	33.74	47.62	1.54	12.25	10.61	62.65
“ 18..	373	1372	11	2.40	1.66	....	0.0101	2.10	62.26	30.66	7.09	13.14	86.86	18.08	32.76	47.66	1.56	13.72	10.06	68.75
“ 19..	382	1381	12	2.28	1.66	....	0.0107	1.98	58.52	33.59	7.88	12.70	87.30	17.89	33.83	47.32	1.46	13.26	11.36	66.97
“ 20..	394	1393	13	2.29	1.66	....	0.0115	1.91	56.02	35.20	8.79	13.28	86.72	17.32	33.45	47.68	1.55	13.54	11.81	65.43
“ 22..	420	1419	14	2.33	1.67	....	0.0118	2.07	58.89	33.17	7.94	12.92	87.08	17.29	33.82	47.19	1.695	13.33	11.20	66.91
“ 23..	431	1430	15	2.34	1.71	4.82	0.0117	2.08	57.42	34.21	8.37	12.96	87.04	16.75	33.80	47.82	1.60	13.17	11.56	66.27
“ 24..	442	1441	16	2.30	1.68	5.77	0.0118	2.02	55.80	34.89	9.81	13.04	86.96	17.25	33.82	47.36	1.57	13.22	11.80	64.59
“ 25..	455	1454	17	2.30	1.67	4.35	0.0123	2.00	56.54	34.77	8.70	12.52	87.48	16.89	34.50	46.97	1.69	12.94	11.98	65.77
“ 26..	466	1465	18	2.28	1.67	....	0.0123	1.98	56.10	34.85	9.02	12.42	87.58	16.16	34.46	47.71	1.67	12.60	12.00	65.81
“ 28..	488	1487	19	2.22	1.69	4.46	0.0090	1.97	57.11	34.09	8.81	13.12	86.88	17.59	33.00	47.82	1.59	14.39	11.26	65.97
“ 29..	500	1499	20	2.08	1.67	....	0.0118	1.98	57.98	33.34	8.68	13.06	86.99	16.71	34.14	47.39	1 76	13.14	11.39	66.16
Totals..............	...			......	......	52.86	0.2316	40.06	1150.87	665.76	147.26	261.46	1738.54	344.94	673.87	949.65	31.53	266.04	225.76	1317.82
Averages..............				2.277	1.696	4.80	0.0122	2.00	57.54	33.28	8.66	13.07	86.927	17.247	33.69	47.48	1.577	13.32	11.288	65.89

AMERICAN RED No. 340.

1905.	Analysis No..	Laboratory No..........	No. of egg....	Long diameter of egg...	Short diameter of egg...	Weight to perforate shell.	Av. thickness of shell, in inches	Wt. of egg, in ounces....	Percentage of white.......	Percentage of yolk.........	Percentage of shell.........	Percentage of protein in white.......	Percentage of water in white.......	Percentage of protein in yolk.........	Percentage of ether extract in yolk.	Percentage of water in yolk.........	Percentage of ash in yolk..	Percentage of protein in egg.........	Percentage of ether extract in egg.	Percentage of water in egg. ....
Jun. 19..	25	1024	1	......	......	....	0.0148	2.02	57.45	29.85	....	11.80	88.20	19.27	30.61	48.60	1.52	12.53	9.12	65.18
" 20..	36	1035	2	2.24	1.67	5.33	0.0148	2.08	58.22	29.54	....	11.57	88.43	18.27	31.90	48.28	1.61	12.11	9.48	65.75
" 22..	67	1066	3	2.36	1.72	6.64	0.0146	2.21	58.82	30.21	9.41	12.04	87.96	18.06	32.25	48.09	1.55	12.55	9.68	66.28
" 23..	81	1080	4	2.31	1.71	8.96	0.0151	2.14	57.86	32.67	9.47	11.86	88.14	17.64	32.77	48.05	1.54	12.63	10.70	66.70
" 24..	95	1094	5	2.29	1.72	....	0.0144	2.16	60.08	32.80	7.54	11.10	88.90	17.30	33.11	48.00	1.59	12.34	10.86	69.16
" 25..	106	1105	6	2.31	1.74	....	0.0146	2.13	58.34	32.03	9.62	11.55	88.45	16.99	33.27	48.28	1.46	12.19	10.65	67.08
" 26..	124	1123	7	2.28	2.10	4.74	0.0129	2.07	58.88	31.78	9.34	12.14	87.86	17.08	33.96	47.57	1.39	12.56	10.79	66.65
" 27..	137	1136	8	2.30	1.69	4.82	0.0143	2.03	59.30	30.81	9.89	11.65	88.35	16.29	34.33	47.74	1.69	11.93	10.58	67.11
" 28..	152	1151	9	2.24	1.65	7.16	0.0129	1.86	58.38	32.31	9.30	13.24	86 76	17.00	34.31	47.30	1.39	13.22	11.09	65.88
" 29..	169	1168	10	2.19	1.68	7.56	0.0156	1.85	61.58	29.22	10.69	11.69	88.31	17.06	34.21	47.28	1.45	12.17	10.00	68.15
Jul. 1..	201	1200	11	2.34	1.70	5.05	0.0142	2.11	62.82	27.83	9.88	12.48	87.52	16.49	33.39	48.56	1.56	12.36	9.29	68.11
" 2..	216	1215	12	2.23	1.66	....	0.0140	1.91	61.02	29.54	9.43	11.94	88.06	17.02	30.41	51.10	1.47	12.31	9.82	68.88
" 4..	247	1246	13	2.20	1.65	5.80	0.0145	1.91	55.25	35.01	9.66	10.38	89.62	16.78	32.32	49.46	1.44	11.62	11.84	66.89
" 18..	374	1373	14	2.26	1.70	5.87	0.0127	2.01	61.24	29.52	9.25	12.76	87.24	18.53	31.48	48.57	1.42	13.29	9.30	67.79
" 19..	383	1382	15	2.16	1.70	7.48	0.0126	1.91	57.94	32.94	9.13	11.47	88.53	20.08	36.00	42.22	1.75	13.24	11.87	65.30
" 20..	395	1394	16	2.26	1.72	7.74	0.0125	1.98	57.73	33.01	9.27	11.55	88.45	19.49	36.40	42.32	1.795	13.12	12.02	65.18
" 21..	408	1407	17	2.20	1.71	6.76	0.0136	1.97	57.15	33.34	9.52	10.83	89.17	17.84	32.30	48.12	1.74	12.13	10.77	66.94
" 22..	421	1420	18	2.27	1.69	7.07	0.0128	2.00	58.45	32.40	9.14	10.98	89.02	16.87	33.75	47.72	1.66	11.89	10.92	67.53
" 23..	432	1431	19	2.27	1.68	7.54	0.0134	2.01	58.51	31.59	9.33	10.59	89.41	16.46	33.70	48.26	1.58	11.39	10.65	67.63
" 24..	443	1442	20	2.35	1.65	....	0.0133	1.97	58.32	31.88	10.29	11.49	88.51	16.08	34.25	48.00	1.67	11.73	10.74	66.67
" 25..	456	1455	21	2.21	1.68	7.08	0.0148	1.91	59.41	29.73	10.86	11.80	88.20	16.87	34.10	47.93	1.595	11.88	10.14	66.65
" 27..	478	1477	22	2.33	1.72	4.59	0.0138	2.17	62.75	27.30	9.95	12.28	87.72	16.69	34.00	47.62	1.69	12.27	9.28	68.04
" 28..	489	1488	23	2.07	1.68	4.84	0.0136	1.96	60.88	29.52	10.10	11.53	88.41	17.30	32.35	48.70	1.65	12.08	9.54	67.80
" 29..	501	1500	24	2.23	1.65	4.10	0.0136	1.89	59.55	30.18	10.25	12.12	87.88	16.71	33.41	48.18	1.70	12.25	10.10	66.90
Totals.................				......	......	118.63	0.3190	48.26	1418.94	744.51	211.82	280.84	2119.16	417.56	798.58	1145.95	37.86	295.77	247.73	1540.14
Averages..............				2.195	1.634	6.243	0.1329	2.01	59.12	31.02	9.63	11.70	88.298	17.40	33.27	47.748	1.577	12.32	10.32	64.17

PLYMOUTH ROCK No. 7.

Date. 1905.	Analysis No.	Laboratory No.	No. of egg.	Long diameter of egg.	Short diameter of egg.	Weight to perforate shell.	Av. thickness of shell, in inches.	Wt. of egg, in ounces.	Percentage of white.	Percentage of yolk.	Percentage of shell.	Percentage of protein in white.	Percentage of water in white.	Percentage of protein in yolk.	Percentage of ether extract in yolk.	Percentage of water in yolk.	Percentage of ash in yolk.	Percentage of protein in egg.	Percentage of ether extract in egg.	Percentage of water in egg.
Jun. 27..	131	1130	1	2.25	1.58	5.12	0.0127	1.74	56.40	34.38	9.18	12.78	87.22	19.28	30.20	49.14	1.38	13.32	10.44	66.07
" 28..	144	1143	2	2.17	1.58	4.77	0.0145	1.71	53.70	35.71	10.61	10.26	89.74	18.33	31.86	48.15	1.66	12.06	11.38	65.28
" 30..	177	1176	3	2.25	1.59	7.44	0.0144	1.74	54.08	35.34	10.58	11.12	88.88	18.04	31.06	49.29	1.61	12.38	11.97	65.50
Jul. 1..	193	1192	4	2.32	1.55	5.51	0.0137	1.75	53.84	35.59	10.58	11.53	88.47	17.59	31.61	49.20	1.60	12.51	11.26	65.12
" 3..	224	1223	5	2.10	1.57	6.24	0.0148	1.86	55.04	34.83	10.13	11.39	88.61	17.60	30.78	50.07	1.55	12.41	10.73	66.22
" 5..	252	1251	6	2.17	1.61	....	0.0148	1.78	56.54	33.32	10.15	11.63	88.37	19.18	31.14	48.09	1.59	12.96	10.35	65.99
" 8..	282	1281	7	2.25	1.64	....	0.0140	1.90	58.48	32.56	9.83	12.10	87.90	18.54	31.64	48.39	1.43	13.10	10.30	67.11
" 9..	293	1292	8	2.21	1.61	9.22	0.0143	1.77	53.75	35.06	11.19	11.20	88.80	18.54	30.86	49.01	1.29	12.51	10.82	64.88
" 10..	299	1298	9	2.14	1.62	7.34	0.0142	1.79	55.38	33.70	10.92	10.18	89.82	18.69	30.80	48.95	1.56	11.94	10.40	66.20
" 12..	321	1320	10	2.24	1.63	6.96	0.0145	1.94	54.96	32.45	10.77	11.04	88.96	17.11	32.80	48.68	1.41	11.63	10.65	64.64
" 13..	330	1329	11	2.15	1.62	6.60	0.0141	1.73	55.58	33.60	10.81	11.41	88.59	18.28	32.20	48.09	1.43	12.48	10.82	65.86
" 15..	347	1346	12	2.16	1.60	7.56	0.0129	1.72	56.62	33.28	10.09	12.10	87.90	18.15	30.63	49.64	1.53	12.36	10.18	66.32
" 16..	354	1353	13	2.12	1.61	3.63	0.0133	1.73	59.80	32.49	9.74	11.12	88.89	18.83	30.66	49.40	1.61	12.36	9.96	67.40
Totals				......	......	....	....	......	....	....	....	....	....	....	....	....	......	....	....	....
Averages				2.19	1.60	6.399	0.0140	1.78	55.70	34.02	10.35	11.37	88.63	18.28	31.25	48.92	1.54	12.54	10.71	65.86

PLYMOUTH ROCK No. 9.

Date. 1905.	Analysis No.	Laboratory No.	No. of egg.	Long diameter of egg.	Short diameter of egg.	Weight to perforate shell.	Av. thickness of shell, in inches	Wt. of egg, in ounces.	Percentage of white.	Percentage of yolk.	Percentage of shell.	Percentage of protein in white.	Percentage of water in white.	Percentage of protein in yolk.	Percentage of ether extract in yolk.	Percentage of water in yolk.	Percentage of ash in yolk.	Percentage of protein in egg.	Percentage of ether extract in egg.	Percentage of water in egg.
Jun. 19	17	1016	1	2.30	1.63	....	0.0147	1.94	50.50	37.12	....	....	....	17.63	31.67	49.08	1.67	....	11.75	....
" 21	40	1039	2	2.25	1.58	7.95	0.0150	1.82	50.48	37.34	....	11.76	88.24	16.73	32.91	48.85	1.51	12.19	12.25	62.81
" 22	54	1053	3	2.28	1.61	4.00	0.0147	1.82	52.34	37.76	9.90	11.73	88.27	16.74	33.57	48.12	1.57	12.45	12.68	64.35
" 23	73	1072	4	2.18	1.63	3.84	0.0149	1.87	52.12	37.51	10.39	11.20	88.80	17.29	33.40	47.79	1.52	12.32	10.05	64.18
" 24	87	1086	5	2.23	1.63	....	0.0147	1.85	49.29	38.10	10.69	12.08	87.92	16.37	34.26	47.88	1.49	12.19	13.12	61.63
" 25	99	1098	6	2.12	1.64	6.29	0.0160	1.92	52.90	36.24	10.86	11.53	88.47	16.23	34.28	47.94	1.55	11.97	12.46	64.21
" 26	113	1112	7	2.04	1.55	6.72	0.0148	1.52	55.85	32.89	11.27	....	....	16.27	32.73	49.68	1.32	....	10.76	....
" 28	140	1139	8	2.30	1.64	5.14	0.0148	1.92	54.91	35.06	10.40	11.96	88.04	17.13	33.26	47.96	1.65	12.57	11.66	65.12
" 29	159	1158	9	2.17	1.61	7.64	0.0153	1.76	54.36	34.49	11.16	8.55	91.45	15.81	33.98	48.85	1.41	10.10	11.70	66.56
" 30	174	1173	10	2.17	1.63	....	0.0143	1.75	53.60	35.75	10.64	12.42	87.58	17.10	32.65	48.98	1.32	12.76	11.67	64.42
Jul. 1	191	1190	11	2.14	1.59	5.96	0.0105	1.71	58.35	34.60	7.88	11.53	88.47	16.65	32.83	48.94	1.58	12.50	11.10	68.67
" 3	221	1220	12	2.20	1.60	5.04	0.0146	1.76	55.64	33.73	10.63	12.76	87.24	17.29	31.07	50.21	1.43	12.93	10.46	65.51
" 4	238	1237	13	2.13	1.59	5.88	0.0157	1.69	56.80	32.32	10.87	11.80	88.20	17.67	31.48	49.19	1.46	12.48	10.17	69.98
" 6	262	1261	14	1.99	1.57	....	0.0137	1.53	58.25	32.35	9.39	12.00	88.00	18.39	31.80	48.29	1.52	12.94	10.29	66.92
" 20	388	1387	15	2.16	1.56	7.20	0.0140	1.58	56.26	32.64	11.10	12.58	87.42	18.07	29.80	51.23	1.40	12.98	9.56	65.96
" 23	425	1424	16	2.19	1.57	8.86	0.0145	1.70	54.95	34.07	10.97	12.88	87.12	17.52	31.20	49.71	1.57	13.05	10.64	54.84
" 24	437	1436	17	2.14	1.58	8.78	0.0190	1.68	52.77	34.65	12.59	12.28	87.72	18.75	30.27	49.40	1.58	12.95	10.50	63.37
" 26	459	1458	18	2.33	1.57	10.75	0.0164	1.78	52.41	35.12	12.48	12.46	87.54	18.41	30.72	49.18	1.69	12.98	10.88	63.16
" 28	483	1482	19	2.19	1.62	3.48	0.0117	1.75	55.82	35.50	8.68	11.74	88.36	17.97	31.36	48.98	1.69	12.95	11.14	66.68
Totals				......	......	....	0.2793	33.35	1027.68	667.24	179.84	201.26	1498.74	328.22	612.69	930.16	28.93	212.31	212.77	1108.37
Averages				2.18	1.60	6.499	0.0147	1.75	54.088	35.118	10.58	11.84	88.16	17.27	32.247	48.95	1.52	12.49	11.198	65.198

PLYMOUTH ROCK No. 10.

DATE. 1905.	Analysis No.	Laboratory No.	No. of egg.	Long diameter of egg.	Short diameter of egg.	Weight to perforate shell.	Av. thickness of shell, in inches.	Wt. of egg in ounces.	Percentage of white.	Percentage of yolk.	Percentage of shell.	Percentage of protein in white.	Percentage of water in white.	Percentage of protein in yolk.	Percentage of ether extract in yolk.	Percentage of water in yolk.	Percentage of ash in yolk.	Percentage of protein in egg.	Percentage of ether extract in egg.	Percentage of water in egg.
Jun. 19..	18	1017	1	2.20	1.78	....	0.0154	2.14	56.90	31.06	... .	10.27	89.73	18.46	32.86	46.98	1.75	11.58	9.99	65.60
" 20..	30	1029	2	2.23	1.74	....	0.0150	2.20	56.93	31.79	....	13.88	86.22	19.37	33.55	45.56	1.52	14.00	10.69	63.57
" 22..	55	1054	3	2.22	1.71	....	0.0139	2.02	61.32	30.14	8.67	14.63	85.87	17.90	30.38	50.16	1.56	14.38	9.16	67.50
" 24..	88	1087	4	2.34	1.61	....	0.0157	1.87	54.37	35.22	10.44	12.08	87.92	18.58	32.73	47.21	1.48	13.10	10.35	64.39
" 26..	114	1113	5	2.25	1.76	8.34	0.0137	2.12	60.50	30.31	9.16	12.34	87.66	16.67	32.40	49.33	1.60	12.51	9.71	67.97
" 28..	141	1140	6	2.24	1.71	5.25	0.0141	2.01	61.02	29.43	9.56	12.28	87.72	17.72	31.76	48.95	1.57	12.71	9.34	67.98
" 29..	160	1159	7	2.08	1.68	6.97	0.0157	1.87	59.47	30.09	12.30	12.56	87.44	17.30	31.01	50.13	1.55	12.67	9.34	67.11
" 30..	175	1174	8	2.12	1.67	6.30	0.0148	1.82	58.46	31.53	9.95	12.00	88.00	18.02	31.49	49.08	1.41	12.70	9.95	66.97
Jul. 2..	206	1205	9	2.10	1.69	6.30	0.0151	1.84	58.45	31.46	10.11	12.54	87.46	18.51	30.75	49.33	1.41	13.15	9.67	66.70
" 4..	239	1238	10	2.21	1.71	....	0.0151	2.10	61.20	29.17	9.62	12.22	87.78	18.75	31.49	48.32	1.44	12.94	9.19	67.80
" 7..	278	1272	11	2.12	1.70	6.60	0.0143	1.95	62.61	26.92	10.47	11.31	88.69	18.92	30.24	49.49	1.35	12.17	8.14	68.92
" 9..	291	1290	12	2.04	1.74	8.27	0.0141	1.98	60.34	29.61	10.05	12.62	87.38	18.13	31.17	49.25	1.45	12.98	9.23	67.32
" 11..	309	1308	13	2,23	1.72	....	0.0138	2.08	60.81	29.39	9.81	12.50	87.50	18.51	31.95	48.14	1.40	13.08	9.32	67.40
" 12..	319	1318	14	2.45	1.82	....	0.0145	2.46	63.27	27.78	9.00	11.57	89.43	18.41	31.68	48.51	1.40	12.43	8.79	70.09
" 13..	328	1327	15	2.25	1.71	9.62	0.0149	2.04	58.49	31.06	10.46	12.16	87.84	17.95	32.44	48.07	1.54	12.69	10.08	66.36
" 15..	345	1344	16	2.15	1.72	4.98	0.0141	1.92	61.12	29.97	8.89	11.92	88.08	17.20	30.88	50.34	1.57	12.44	9.27	68.96
" 18..	368	1367	17	2.18	1.68	....	0.0137	1.87	40.68	31.26	9.28	....	....	18.44	29.45	51.57	1.53	....	9.13	....
" 20..	389	1388	18	2.25	1.72	7.17	0.0139	2.10	59.10	31.16	9.74	11.78	88.22	17.81	30.40	50.40	1.30	12.53	9.46	67.90
Totals				.....	.....	....	0.2616	36.36	1054.96	547.36	157.51	208.66	1492.44	326.65	566.63	880.77	26.84	218.01	170.81	1142.54
Averages				2.26	1.711	6.98	0.0145	2.02	58.61	30.41	9.845	12.27	87.79	18.146	31.48	48.93	1.49	12.82	9.49	67.21

WHITE WYANDOTTE No. 4C12.

DATE. 1905.	Analysis No.	Laboratory No.	No. of egg.	Long diameter of egg.	Short diameter of egg.	Weight to perforate shell.	Av. thickness of shell, in inches.	Wt. of egg, in ounces.	Percentage of white.	Percentage of yolk.	Percentage of shell.	Percentage of protein in white.	Percentage of water in white.	Percentage of protein in yolk.	Percentage of ether extract in yolk.	Percentage of water in yolk.	Percentage of ash in yolk.	Percentage of protein in egg.	Percentage of ether extract in egg.	Percentage of water in egg.
Jun. 29..	167	1166	1	2.23	1.62	4.90	0.0137	1.80	57.86	32.27	9.85	13.42	86.58	17.40	31.32	49.65	1.63	13.38	10.10	66.09
Jul. 1..	196	1195	2	2.27	1.69	8.13	0.0139	2.03	56.13	33.00	10.85	14.67	85.33	18.71	30.73	49.20	1.36	14.30	10.14	64.04
" 2..	212	1211	3	2.21	1.70	6.18	0.0148	2.01	57.94	32.17	9.90	12.86	87.14	17.90	31.26	49.22	1.62	13.20	10.03	66.30
" 3..	229	1228	4	2.22	1.73	7.90	0.0144	2.08	56.27	33.78	9.96	11.67	88.33	17.56	31.33	49.40	1.71	12.49	10.58	66.36
" 4..	244	1243	5	2.23	1 70	8 06	0.0157	2.07	57.06	32.45	10.49	12.16	87.84	18.32	31.61	48.55	1.52	12.88	10.23	65.95
" 5..	256	1255	6	2.29	1.70	6.42	0.0143	2.01	58.78	32.68	9.98	12.60	87.40	17.84	33.05	47.50	1.61	13.24	10.80	66.93
" 6..	260	1265	7	1.84	1.70	8.24	0.0157	2.01	56.18	32.73	11.07	12.30	87.70	17.88	32.38	48.28	1.46	12.77	10.59	65.13
" 8..	283	1282	8	2.30	1.69	10.06	0.0154	2.13	58.57	30.41	11.02	12.06	87.94	16.97	33.15	48 27	1.61	12.22	10.07	66.14
" 9..	295	1294	9	2.15	1.64	9.36	0.0150	1.82	62.15	28.98	10.80	12.38	87.62	18.60	31.44	48.49	1.46	13.08	9.15	68.52
" 10..	301	1300	10	2.20	1.71	7.11	0.0145	2.03	58.98	30.40	10.60	12.04	87.96	18.77	31.33	48.55	1.35	12.80	9.52	66.58
" 11..	312	1311	11	2.17	1.70	9.74	0.0171	1.99	57.06	30.18	12.77	13.18	86.83	17.52	33.05	47.87	1.56	12.81	9.96	64 06
" 13..	331	1330	12	2.28	1.72	8.54	0.0149	2.05	56.75	32.42	10.85	12.94	87.06	16.82	33.50	48.18	1.50	12.80	10.84	65.04
" 14..	338	1337	13	2.24	1.78	....	0.0151	2.18	59.68	29.99	10.34	11.41	88.59	17.86	32.42	48.37	1.35	12.16	9.72	67.38
" 15..	348	1347	14	2.22	1.71	6.72	0.0148	2.01	57.55	31.86	10.23	13.14	86 86	17.55	32.15	48.90	1.40	13.15	10.24	65.58
" 16..	355	1354	15	2.19	1.72	8.33	0.0155	2.03	56.72	31.88	11.38	12.78	87.22	17.24	32.13	49.04	1.59	12.76	10.24	65.15
" 18..	370	1359	16	2.07	1.71	5.84	0.0143	2.06	57.53	32.18	10.28	12.76	87.24	17.99	32.07	48.43	1.51	13.12	10.33	65.78
" 19..	379	1378	17	2.31	1.73	7.28	0.0136	2.09	61.28	30.62	8.08	11.74	88.26	16.93	33.37	48.05	1.64	12.38	10.22	68.82
" 20..	393	1392	18	2.25	1.70	6.20	0.0135	2.01	57.07	33.14	9.79	12.24	87.76	17.24	32.35	48.79	1.62	12.70	10.72	66.26
" 21..	404	1403	19	2.26	1.70	8 91	0.0159	2.05	56.32	32.45	11.22	11.67	88.33	17.83	31.45	49.17	1.55	12.35	10.19	65.66
" 23..	429	1428	20	2.30	1.70	9.48	0.0144	2.03	58.50	30.84	10.74	11.72	88.28	17.67	31.92	48.75	1.66	12.31	9.84	66.66
" 25..	451	1450	21	2.32	1.70	5.40	0.0135	2.03	59.70	30.56	9.71	12.28	87.72	17.38	31.92	49.09	1.61	12.64	9.75	67.37
" 27..	475	1474	22	2.36	1.69	8.58	0.0145	2.12	60.98	28.66	10.35	11.90	88.10	17.24	32.07	49.00	1.69	12.19	9.20	67.72
" 29..	496	1495	23	2.26	1.72	....	0.0141	2.13	58.28	31.81	9.92	12.66	87.34	18.67	31.15	48.64	1.53	13.31	9.92	66.38
Totals																				
Averages				2.224	1.70	7.68	0.0147	2.08	58.14	31.54	10.44	12 46	87.54	17.73	32.05	48 67	1.54	12.83	10.10	66.25

The preceding tables afford data for much study, though perhaps generalizations cannot be arrived at as rapidly as might be expected. For example, in respect to the weights of the eggs, study of the tables shows that a hen may be credited with an egg each day for several days and then a day is skipped, or perhaps more than one day. In many instances it may be seen that during the time that the eggs are laid daily the weight becomes constantly smaller, then after a day or two of rest the eggs produced are again larger. This succession of variations in the weight is illustrated very well by the Single Comb White Leghorns Nos. 21 and 51. For example, with No. 51, beginning with June 18 the egg weights in ounces for four days were 1.91, 1.94, 1.89 and 1.76; June 22 no egg was laid, and the next four days the weights were 1.82, 1.77, 1.75 and 1.83; no egg was laid June 27, and the next three days the weights were 1.86, 1.79 and 1.70; no egg was laid July 1, and the weights for the next three days were 1.81, 1.78 and 1.73; July 5 was skipped, and on the 6th and 7th the weights were 1.94 and 1.97; none was laid on the 8th, and the weights for the 9th and 10th were 1.85 and 1.80; on the 11th none was laid, and the weights for the next four days were 1.93, 1.86, 1.83 and 1.77; two days were then skipped, and the weights for the next four days were 1.94, 1.79, 1.74 and 1.62; July 22 no egg was laid, and the next three days the weights were 1.83, 1.77 and 1.71; no egg was laid on the 26th, and the weights for the next three days were 1.83, 1.82 and 1.90. It will be seen that there are here several striking series of the kind indicated, in which a day with no egg followed a continued diminution in the size and preceded a series beginning with an increased weight. On the other hand, there are several exceptions to the regularity of change. Such studies as these are possible only where the hens are laying nearly every day. The Single Comb White Leghorn No. 21 affords similar illustrations, but numerous examples may be found in the tables in which this regularity is not exhibited. On the whole, however, a tendency in this direction must be conceded.

In respect to the thickness of shell no great variations are displayed, though, as would be expected, some differences are observable, which in the case of extremes amounts to about 20 per cent. Thus the White Wyandotte B1B shows an average thickness of .012 inches, while the White Leghorn No. 21 lot gave the average thickness of the shells as .015 inches. The averages for the breeds, as shown in a later table, show differences that are practically negligible.

Closely connected with thickness of shell is the factor of weight necessary to perforate the shell, and as would be expected the thinner shells are on the average shown to be perforated by less weights. If the data for individual eggs be examined, however, it will be found that there are many cases of discrepancy. This is doubtless due to the obvious difficulties in getting correct results, especially as only one point in the shell can be tested with reference to perforation. For these numbers we must depend on averages altogether, such as are shown in a table on a later page.

Leaving then the consideration of tables concerning individual eggs for study by the reader with reference to any points in which he is interested upon which data are recorded, attention may be directed to the table of averages for each hen, each breed, and the four breeds. But little can be done in the way of summarizing so condensed a statement as the table presents, but it will be seen that the different breeds do not on the average show any very marked differences, and even the averages for the individual hens are strikingly near the general averages for the four breeds as a rule. Perhaps as important a difference as any is shown in the percentage of ether extract in the yolk, running from 31.8 in the Single Comb White Leghorns to 32.87 in the American Reds. The percentages of protein in the yolk show a corresponding variation, ranging from 17.83 with the Leghorns to 17.18 in the American Reds.

DATA CONCERNING EGGS, SHOWING AVERAGES OF INDIVIDUALS AND BREEDS AND GENERAL AVERAGES.

HEN.	Long diameter of egg...	Short diameter of egg...	Weight to perforate shell.	Av. thickness of shell, in inches......	Wt. of egg, in ounces...	Percentage of white.......	Percentage of yolk.........	Percentage of shell........	Percentage of protein in white.......	Percentage of water in white.......	Percentage of protein in yolk.........	Percentage of ether extract in yolk.	Percentage of water in yolk.........	Percentage of ash in yolk..	Percentage of protein in egg........	Percentage of ether extract in egg.	Percentage of water in egg.........
American Red No. 3.....	58.13	41.64	5.95	0.0133	1.91	56.94	33.87	9.27	10.61	89.39	16.82	33.76	47.82	1.58	11.97	11.45	67.20
" No. 6.....	55.50	41.60	6.67	0.0135	1.80	53.43	36.34	9.78	11.35	88.65	16.92	31.72	49.87	1.62	12.30	11.49	65.95
" No. 214.....	55.50	40.40	6.50	0.0140	1.76	57.02	32.88	10.52	12.56	87.44	17.49	31.90	49.06	1.53	12.83	10.33	65.72
" No. 218.....	57.98	43.13	4.80	0.0122	2.00	57.54	33.29	8.66	13.07	86.98	17.25	33.69	47.48	1.57	13.32	11.29	65.89
" No. 340.....	57.40	43.80	6.24	0.0133	2.01	59.12	31.62	9.63	11.70	88.30	17.40	33.27	47.75	1.58	12.32	10.32	64.17
Averages	56.90	42.11	6.03	0.0133	1.90	56.81	33.38	9.57	11.86	88.14	17.18	32.87	48.39	1.58	12.55	10.98	65.79
Plymouth Rock No. 7.....	55.50	40.67	6.50	0.0147	1.75	54.09	35.12	10.58	11.84	88.16	17.27	32.25	48.95	1.52	12.49	11.20	65.20
" No. 10.....	56.05	43.67	6.98	0.0145	2.02	58.61	30.41	9.85	12.27	87.79	18.15	31.48	48.93	1.49	12.82	9.49	67.21
" No. 45.....	57.90	40.71	6.23	0.0144	1.85	57.15	32.64	10.19	11.23	88.77	18.00	32.07	48.47	1.54	12.28	10.46	66.56
" No. 67.....	55.50	41.50	5.45	0.0135	1.83	57.63	32.65	9.72	12.10	87.90	17.32	32.68	48.42	1.58	12.59	10.60	66.40
" No. 70....	55.86	40.70	6.40	0.0140	1.78	55.70	34.02	10.35	11.37	88.63	18.28	31.25	48.92	1.54	12.54	10.71	65.86
" No. 98.....	56.10	41.90	6.40	0.0136	1.87	57.11	33.12	9.87	12.65	87.35	17.49	32.11	48.75	1.63	12.98	10.62	65.95
Averages..............	56.15	41.53	6.33	0.0141	1.85	56.72	32.99	10.09	11.91	88.10	17.75	31.97	48.74	1.55	12.62	10.51	66.20
S. C. White Leghorn No. 3	54.20	41.15	7.02	0.0149	1.76	58.04	31.16	10.85	12.77	87.23	18.35	31.39	48.69	1.56	13.09	9.98	65.85
" " No. 7	57.75	42.95	5.93	0.0135	2.02	59.39	30.53	9.58	13.23	86.76	17.71	32.32	48.37	1.58	13.25	9.87	66.32
" " No. 19	54.55	40.23	6.33	0.0139	1.67	56.38	31.14	10.42	12.53	87.47	17.79	30.83	49.51	1.49	12.95	10.34	65.78
" " No. 21	55.17	40.28	6.74	0.0150	1.71	55.48	33.21	11.45	12.48	87.52	17.90	32.08	48.43	1.58	12.97	10.74	64.91
" " No. 50	56.20	41.66	5.28	0.0137	1.99	55.91	34.23	9.66	12.66	87.33	17.45	31.71	49.35	1.49	13.06	10.85	65.71
" " No. 51	56.20	41.60	7.24	0.0146	1.82	54.08	35.29	10.82	11.78	88.22	17.77	32.49	48.21	1.58	12.58	11.38	64.78
Averages	55.68	41.31	6.42	0.0143	1.83	56.55	32.59	10.46	12.58	87.42	17.83	31.80	48.76	1.55	12.97	10.53	65.55
White Wyandotte No. 4A4	54.60	42.30	8.06	0.0141	1.87	56.15	33.43	10.21	13.12	86.88	17.58	32.72	48.17	1.53	13.24	10.94	64.76
" No 4A7	54.80	42.30	6.17	0.0135	1.87	60.57	29.58	9.79	13.41	86.60	17.33	32.91	48.17	1.50	13.23	9.68	66.71
" No. B1B	55.00	43.30	4.73	0.0120	1.90	57.48	33.63	8.43	12.97	87.08	17.68	32.26	48.55	1.60	13.36	10.86	66.34
" No. 4C9	56.90	43.78	6.40	0.0139	2.06	58.73	31.56	9.72	13.32	86.68	17.54	33.08	47.85	1.57	13.30	10.44	66.09
" No. 4C11	57.40	43.30	6.33	0.0145	2.09	56.60	33.20	10.00	12.39	87.61	17.13	31.25	50.07	1.48	12.70	10.41	66.12
" No. 4C12	56.60	43.30	7.68	0.0147	2.08	58.14	31.64	10.44	12.46	87.54	17.73	32.05	48.67	1.54	12.83	10.10	66.25
Averages..............	55.88	43.05	6.56	0.0138	1.97	57.95	32.16	9.77	12.95	87.06	17.50	32.37	48.58	1.54	13.11	10.41	66.05
General averages......	56.12	41.98	6.35	0.0139	1.88	57.01	32.75	9.99	12.34	87.66	17.58	32.23	48.63	1.55	12.83	10.59	65.90

DETERMINATIONS OF PHOSPHORUS IN YOLKS.

In the four accompanying tables are exhibited the results of determinations of phosphorus in composite samples from the yolks of eggs laid within each of the weeks of the experiment. Where no results are shown no eggs were laid within that week by that hen. The results are expressed in terms of phosphoric acid, P_2O_5. In the determinations one gram of the air-dry yolk was digested in a Kjeldahl flask with potassium sulfate and concentrated sulfuric acid, as for the determination of nitrogen. The product was diluted with 100 cubic centimeters of water and boiled again. This solution was made up to 250 cubic centimeters in a volumetric flask and 100 cubic centimeter portions used in making the duplicate analyses. The phosphoric acid was precipitated by a molybdic solution according to the official methods, and this precipitate was dissolved and the phosphoric acid determined as magnesium pyrophosphate in the usual manner.

The per cent. of ash was also determined in one gram of the air-dry sample. The results in the cases of both ash and phosphoric acid are calculated to the original substance. Study of the results shows considerable variations in the ratio of phosphoric acid to ash in individual composite samples, but the differences are much less for the average results of the different hens. For the four breeds the averages are: American Red, 1 of phosphoric acid to 1.09 of ash in the yolk; Plymouth Rock, 1: 1.11; White Leghorn, 1: 1.09; White Wyandotte, 1: 1.08. The average of these four practically identical results is 1: 1.093. It is evident that the ash consists almost entirely of phosphoric acid. This is doubtless produced almost entirely, if not altogether, from the lecithin of the egg yolk. It is proper to mention in this connection that all of the determinations of phosphoric acid and ash were made by Miss Gertrude Hole, a graduate student in the department.

AMERICAN RED.

Hen.	Date limits.	Percentage of ash in yolk...	Percentage of phosphoric acid in yolk...	Ratio of phosphoric acid to ash in yolk...
American Red No. 3	June 18 to June 25	1.58	1.50	1:1.05
" "	June 25 to July 2	1.52	1.46	1:1.04
" "	July 2 to July 9	1.53	1.50	1:1.02
" "	July 9 to July 16	1.61	1.42	1:1.13
" "	July 16 to July 23	1.64	1.46	1:1.12
" "	July 23 to July 30	1.64	1.48	1:1.10
Averages		1.59	1.47	1:1.08
American Red No. 6	June 18 to June 25	1.65	1.54	1:1.07
" "	June 25 to July 2	1.50	1.07	1:1.40
" "	July 2 to July 9	1.41	1.32	1:1.06
" "	July 9 to July 16			
" "	July 16 to July 23	1.74	1.40	1:1 24
" "	July 23 to July 30	1.68	1.52	1:1.10
Averages		1.60	1.37	1:1.17
American Red No. 214	June 18 to June 25	1.47	1.33	1:1.15
" "	June 25 to July 2	1.48	1.38	1:1.08
" "	July 2 to July 9	1.50	1.39	1:1.08
" "	July 9 to July 16	1.50	1.35	1:1.11
" "	July 16 to July 23	1.53	1.41	1:1.08
" "	July 23 to July 30	1.66	1.40	1:1.19
Averages		1.52	1.38	1:1.10
American Red No. 218	June 18 to June 25	1.66	1.57	1:1.05
" "	June 25 to July 2	1.45	1.31	1:1.10
" "	July 2 to July 9	1.54	1.47	1:1.04
" "	July 9 to July 16			
" "	July 16 to July 23	1.57	1.45	1:1.08
	July 23 to July 30	1.64	1.50	1:1.09
Averages		1.57	1.46	1:1.07
American Red No. 340	June 18 to June 25	1.57	1.51	1:1.04
" "	June 25 to July 2	1.48	1.39	1:1.06
" "	July 2 to July 9	1.45	1.38	1:1.05
" "	July 9 to July 16			
" "	July 16 to July 23	1.67	1.49	1:1.12
	July 23 to July 30	1.65	1.49	1:1.10
Averages		1.56	1.45	1:1 08
Averages of breed		1.57	1.43	1:1.09

PLYMOUTH ROCK.

HEN.	Date limits.	Percentage of ash in yolk...	Percentage of phosphoric acid in yolk...	Ratio of phosphoric acid to ash in yolk...
Plymouth Rock No. 7	June 18 to June 25	1.55	1.29	1:1.20
" "	June 25 to July 2	1.47	1.35	1:1.09
" "	July 2 to July 9	1.47	1.30	1:1.13
" "	July 9 to July 16	....	....	....
" "	July 16 to July 23	1.40	1.26	1:1.11
" "	July 23 to July 30	1.63	1.34	1:1.21
Averages		1.50	1.31	1:1.14
Plymouth Rock No. 10	June 18 to June 25	1.58	1.40	1:1.12
" "	June 25 to July 2	1.53	1.33	1:1.14
" "	July 2 to July 9	1.40	1.37	1:1.05
" "	July 9 to July 16	1.47	1.34	1:1.09
" "	July 16 to July 23	1.47	1.27	1:1.15
" "	July 23 to July 30	....	....	....
Averages		1.49	1.34	1:1.11
Plymouth Rock No. 45	June 18 to June 25	1.54	1.44	1:1.07
" "	June 25 to July 2	1.55	1.43	1:1.08
" "	July 2 to July 9	1.51	1.38	1:1.09
" "	July 9 to July 16	1.56	1.41	1:1.10
" "	July 16 to July 23	1.55	1.43	1:1.08
" "	July 23 to July 30	1.56	1.33	1:1.17
Averages		1.54	1.40	1:1.10
Plymouth Rock No. 67	June 18 to June 25	1.56	1.41	1:1.10
" "	June 25 to July 2	1.56	1.51	1:1.17
" "	July 2 to July 9	1.55	1.47	1:1.06
" "	July 9 to July 16	....	....	....
" "	July 16 to July 23	1.53	1.38	1:1.10
" "	July 23 to July 30	1.64	1.33	1:1.23
Averages		1.57	1.42	1:1.10
Plymouth Rock No. 70	June 18 to June 25	....	....	....
" "	June 25 to July 2	1.56	1.40	1:1.11
" "	July 2 to July 9	1.52	1.32	1:1.15
" "	July 9 to July 16	1.51	1.33	1:1.13
" "	July 16 to July 23	1.61	1.41	1:1.14
" "	July 23 to July 30	....	....	....
Averages		1.55	1.36	1:1.13
Plymouth Rock No. 98	June 18 to June 25	1.52	1.46	1:1.04
" "	June 25 to July 2	1.49	1.39	1:1.07
" "	July 2 to July 9	1.54	1.39	1:1.10
" "	July 9 to July 16	....	....	....
" "	July 16 to July 23	1.68	1.52	1:1.10
" "	July 23 to July 30	1.68	1.45	1:1.15
Averages		1.58	1.44	1:1.09
Averages of breed		1.54	1.38	1:1.11

WHITE LEGHORN.

Hen.	Date limits.	Percentage of ash in yolk...	Percentage of phosphoric acid in yolk...	Ratio of phosphoric acid to ash in yolk...
White Leghorn No. 3	June 18 to June 25	1.52	1.32	1:1.14
" "	June 25 to July 2	1.50	1.46	1:1.03
" "	July 2 to July 9	1.53	1.39	1:1.10
" "	July 9 to July 16	1.60	1.42	1:1.13
" "	July 16 to July 23	1.61	1.41	1:1.14
" "	July 23 to July 30	1.64	1.37	1:1.20
Averages		1.57	1.40	1:1.12
White Leghorn No. 7	June 18 to June 25	1.62	1.48	1:1.09
" "	June 25 to July 2	1.59	1.48	1:1.07
" "	July 2 to July 9	1.50	1.43	1:1.05
" "	July 9 to July 16	1.58	1.45	1:1.09
" "	July 16 to July 23	1.52	1.49	1:1.02
" "	July 23 to July 30	1.69	1.38	1:1.22
Averages		1.58	1.45	1:1.09
White Leghorn No. 19	June 18 to June 23	1.46	1.32	1:1.11
" "	June 23 to July 2	1.50	1.37	1:1.10
" "	July 2 to July 9	1.49	1.44	1:1.03
" "	July 9 to July 16	1.45	1.41	1:1.03
" "	July 16 to July 23	1.46	1.39	1:1.06
" "	July 23 to July 30	1.64	1.42	1:1.15
Averages		1.50	1.39	1:1.08
White Leghorn No. 21	June 21 to June 28	1.55	1.42	1:1.09
" "	June 28 to July 5	1.50	1.41	1:1.06
" "	July 5 to July 12	1.48	1.44	1:1.03
" "	July 12 to July 19	1.66	1.52	1:1.09
" "	July 19 to July 26	1.62	1.40	1:1.15
" "	July 26 to Aug. 2	1.75	1.44	1:1.21
Averages		1.60	1.50	1:1.10
White Leghorn No. 50	June 18 to June 25	1.48	1.41	1:1.06
" "	June 25 to July 2	1.48	1.40	1:1.06
" "	July 2 to July 9	1.52	1.39	1:1.09
" "	July 9 to July 16	1.48	1.44	1:1.03
" "	July 16 to July 23	....	....	... .
	July 23 to July 30	....	....	....
Averages		1.49	1.41	1:1.06
White Leghorn No. 51	June 18 to June 25	1.51	1.31	1:1.15
" "	June 25 to July 2	1.64	1.48	1:1.11
" "	July 2 to July 9	1.56	1.42	1:1.09
" "	July 9 to July 16	1.55	1.47	1:1.05
" "	July 16 to July 23	1.58	1.41	1:1.12
" "	July 23 to July 30	1.65	1.39	1:1.18
Averages		1.58	1.41	1:1 12
Averages of breed		1.55	1.43	1:1 09

WHITE WYANDOTTE.

HEN.	Date limits.	Percentage of ash in yolk...	Percentage of phosphoric acid in yolk...	Ratio of phosphoric acid to ash in yolk ...
White Wyandotte No. 4A4	June 18 to June 25	1.54	1.44	1:1.07
" "	June 25 to July 2	1.51	1.46	1:1.03
" "	July 2 to July 9	1.55	1.44	1:1.08
" "	July 9 to July 16	......	......	......
" "	July 16 to July 23	......	......	......
" "	July 23 to July 30	......	......	......
Averages		1.53	1.45	1:1.06
White Wyandotte No. B1B	June 18 to June 25	1.64	1.58	1:1.03
" "	June 25 to July 2	1.52	1.35	1:1.12
" "	July 2 to July 9	1.50	1.43	1:1.05
" "	July 9 to July 16	1.61	1.40	1:1.15
" "	July 16 to July 23	1.67	1.43	1:1.18
" "	July 23 to July 30	1.68	1.47	1:1.14
Averages		1.60	1.44	1:1.11
White Wyandotte No. 4C9	June 21 to June 28	1.57	1.49	1:1.05
" "	June 28 to July 5	1.52	1.39	1:1.09
" "	July 5 to July 12	......	......	......
" "	July 12 to July 19	......	......	......
" "	July 19 to July 26	1.58	1.42	1:1.11
" "	July 26 to Aug. 2	1.62	1.48	1:1.09
Averages		1.57	1.45	1:1.08
White Wyandotte No. 4A7	June 18 to June 25	1.51	1.41	1:1.07
" "	June 25 to July 2	1.48	1.39	1:1.06
" "	July 2 to July 9	1.48	1.39	1:1.06
" "	July 9 to July 16	1.48	1.41	1:1.05
" "	July 16 to July 23	......	......	......
" "	July 23 to July 30	1.63	1.40	1:1.16
Averages		1.51	1,40	1:1.08
White Wyandotte No. 4C11	June 18 to June 25	1.52	1.48	1:1.03
" "	June 25 to July 2	1.47	1.40	1:1.05
" "	July 2 to July 9	1.47	1.45	1:1.01
" "	July 9 to July 16	......	......	......
" "	July 16 to July 23	......	......	......
" "	July 23 to July 30	......	......	......
Averages		1.49	1.44	1:1.03
White Wyandotte No. 4C12	June 18 to June 25	......	......	......
" "	June 25 to July 2	1.50	1.12	1:1.33
" "	July 2 to July 9	1.59	1.41	1:1.12
" "	July 9 to July 16	1.44	1.41	1:1.02
" "	July 16 to July 23	1.58	1.42	1:1.11
	July 23 to July 30	1.63	1.36	1:1.19
Averages		1.55	1.34	1:1.15
Averages of breed		1.54	1.42	1:1.08

SUMMARY.

This Bulletin contains the detailed results of the analyses of all the eggs laid by six pure breeds of chickens within the six weeks from June 18 to July 31, 1905. The weights were also taken as well as the measurements of both diameters of the egg, the thickness of the shell, and its breaking strength. Considerable variations are shown among the eggs laid by individual birds, but the averages in respect to composition are strikingly similar. Determinations of phosphorus were made in composite samples from the yolks of eggs laid within each of the weeks of the experiment. The ratio of the phosphoric acid, P_2O_5, to ash showed considerable variation in individual composite samples, but on the average the results were almost identical for the four breeds, the ratio being 1: 1.093.

THE FOLLOWING BULLETINS ARE AVAILABLE FOR DISTRIBUTION.

No. 12....Preliminary Experiments with Fungicides for Stinking Smut of Wheat.
No. 15....Additional Experiments and Observations on Oat Smut.
No. 17....Crossed Varieties of Corn, Second and Third Years.
No. 38....Preliminary Report on Rusts of Grain.
No. 46....Rusts of Grain, II.
No. 52....Kansas Weeds—Preliminary Circular on Distribution.
No. 54....Experiments with Oats.
No. 117....Bacteria of the Soil.
No. 120....Tests of Forest Trees.
No. 121....Treatment and Utilization of Flood-damaged Lands.
No. 122....Blackleg and Vaccination.
No. 123....Crop Experiments in 1903.
No. 129....Kansas Mammals in their Relation to Agriculture.
No. 130....Steer Feeding Experiment, VII—1903-'04.
No. 135....Grading Cream.
No. 136....Press Bulletins Nos. 125-151.
No. 137....Variations in the Test of Separator Cream.
No. 138....Effect of Bacteria in Wash-water of Butter.
No. 139....The Study of Corn.
No. 140....Milking Machines.
No. 141....Commercial Seeds of Brome-grass, and of English and Kentucky Blue-grasses: Adulterants and Substitutes and their Detection.
No. 142....The Value of Oil in Road Improvement.
No. 143....Disposal of Dairy and Farm Sewage, and Water Supply.
No. 144....Small-grain Crops.
No. 145....Spraying.
No. 146....Kansas Law Regulating the Sale of Concentrated Feeding Stuffs.
No. 148....Law Regulating the Sale of Commercial Fertilizers.
No. 149....Prevention of Sorghum and Kafir-corn Smut.
No. 150....The Hen's Place on the Farm.
No. 151....Alfalfa Breeding.
No. 152....The Pocket Gopher.
No. 153....Deterioration of Red Texas Oats in Kansas.
No. 154....The Mound-building Prairie Ant.
No. 155....Alfalfa.
No. 156....The Yellow Berry Problem in Kansas Hard Winter Wheat.
No. 157....Studies on Hog Cholera and Preventive Treatment.
No. 158....Analyses of Registered Feeding-stuffs.

The Bulletins of the Experiment Station are sent free to applicants. Farmers are invited to send the names of others who would value them and samples will be sent, with return cards upon which applications for future issues may be made.

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Kansas State Agricultural College.

EXPERIMENT STATION.—Bulletin 160.

ED. H. WEBSTER, *Director.*

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FARM BULLETIN.

Agronomy Department.

A. M. TENEYCK, *Agronomist in Charge.*

PLATE I. Cow-peas planted with corn for ensilage.

COW-PEAS.

BY

A. M. TENEYCK, *Agronomist.*
L. E. CALL, *Assistant in Soils.*

MANHATTAN, KAN.,
APRIL 29, 1909.

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Kansas State Agricultural College Experiment Station.

AGRONOMY DEPARTMENT.

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EDWIN G. SCHAFER	Assistant in Crops.
C. S. KNIGHT	Assistant in Farm Machinery.
FLOYD HOWARD	Farm Foreman.

Work of the Agronomy Department.

There are five general lines of work in progress in the Agronomy Department of the Experiment Station, besides special lines of investigation that are taken up from time to time. These general lines are: (1) Variety testing and improvement by selection of all farm crops; (2) planting and cultural tests to determine the best time and method of planting and best methods of preparing the soil and cultivation; (3) soil-fertility experiments, including physical investigation of the soil; (4) harvesting, curing and storing all kinds of farm crops; (5) investigations of the various lines and kinds of farm machinery.

Bulletins are issued from time to time on these subjects, which, with bulletins from other departments of the Station, may be obtained, free of charge, by addressing the Director, Experiment Station, Manhattan, Kan.

Other Departments of the Station Are—

ANIMAL HUSBANDRY	Roland J. Kinzer in charge.
BOTANY	Herbert F. Roberts in charge.
BACTERIOLOGY	Walter E. King in charge.
CHEMISTRY	Julius T. Willard in charge.
DAIRY HUSBANDRY	John C. Kendall in charge.
ENTOMOLOGY	Thomas J. Headlee in charge.
HORTICULTURE	Albert Dickens in charge.
VETERINARY SCIENCE	Francis S. Schoenleber in charge.

COW-PEAS.

INTRODUCTION.

THE cow-pea, botanically named *Vigna unguiculata,* has long been recognized as a valuable crop for the Southern states, where it has been extensively grown for forage and green manuring, but it has only been within comparatively recent years that the general cultivation of this crop has extended into the Northern states. The cow-pea is a native of India, and it is supposed to have been introduced into this country from England in 1734 by the Oglethorpe colonies in Georgia. The cow-pea is an annual leguminous plant, varying in form and habit of growth with the variety, season, soil, moisture and cultural conditions. As a rule, it has a trailing habit of growth, vining profusely during seasons of heavy rainfall. The blossoms are of various colors, ranging from white to purple, while the pods are usually straw-colored when ripe and vary in length from five inches to over a foot. As a rule, the pods do not ripen at the same time. With many varieties there are periods of several weeks when all stages of growth, from blossoms to mature peas, may be found upon the same vine. This makes the time of cutting for seed a difficult matter to judge. The time must be selected for cutting when the largest number of pods are mature and before the peas have started to shell. The seeds vary greatly in size and shape. In color they range from white to the deepest black. The root development is deep for an annual, there being a well-developed tap-root, with a number of large branch roots which start from the upper part of the tap-root, spread horizontally for a short distance and then turn downward. These roots go deeply into the subsoil, enabling the plant to draw freely upon the plant-food and water below the reach of shallower-rooted crops. Upon the numerous small roots in the upper surface of the soil are found the nodules or tubercles which contain the nitrogen-gathering bacteria. These nodules are always present upon the well-developed plants. They enable the plants to make use of the nitrogen of the atmosphere. (Plate X.)

USES OF THE COW-PEA.

HAY.

Cow-peas make excellent hay which, if properly handled, is equal to alfalfa in nutritive value, although as a rule stock do not eat cow-pea hay as readily as alfalfa. When sown for hay it is usually preferable to plant in close drills, requiring about one bushel of seed peas per acre, and when so planted the plants tend to grow more upright, which makes the crop easier to cut with a mower. If grown in rows, although the production of forage may be as great, it is more difficult to harvest, and the ranker growth of the individual plants often makes the hay more woody. It is not an easy matter to cure cow-pea hay; the vines, being so large, cure slowly, and with unfavorable weather the hay is apt to be badly injured, if not spoiled, before it is cured enough to stack. The difficulty of harvesting and curing cow-pea hay, its tendency to become woody, and the lower yield per acre, make this crop, for hay production, less valuable than alfalfa where alfalfa can be successfully grown. In certain sections of the state, where difficulty has been experienced in growing alfalfa, cow-peas fill a need by producing hay and pasture of high feeding value. The crop is also especially valuable as a soil fertilizer when used in rotation with other crops or plowed under as green manure.

The cow-pea is sometimes sown in combination with other crops, such as corn, Kafir-corn, and sorghum for hay. When planted in these combinations there is danger of cow-peas being stunted in growth if the crop with which it is combined is planted too thick. Sown broadcast, cow-peas often make but little growth with these crops, but when planted in rows with corn and cultivated the growth is quite satisfactory.

SOILING AND ENSILAGE.

As a soiling crop cow-peas are very satisfactory. As they should not be planted until the weather and soil are warm, the crop is not available for feed until the latter part of summer, where they fill a place in a well-planned system of soiling and furnish an abundance of succulent green feed, although perhaps less palatable than alfalfa.

When used alone the cow-pea does not make an exceptionally good quality of ensilage, due to the large amount of water in the green vines making a watery silage that keeps poorly and is not well relished by stock. When combined with corn in the proportions of about one-fourth cow-peas to three-fourths corn, it makes an excellent silage that keeps well and is relished by all classes of stock. This combination has greater feeding value than corn silage, for the reason that cow-peas, being relatively high in protein, make the cow-pea-corn silage a more nearly balanced ration.

It is a common practice in dairy sections to grow cow-peas and corn in separate fields and mix them as the silo is being filled. It would seem a more desirable practice to grow the corn and cow-peas together. An experiment along this line was conducted at this Station during 1903, 1904 and 1905, the corn and cow-peas being planted together in rows. When planted the right thickness—corn 12 to 24 inches and peas 4 to 6 inches apart in drill-rows 3½ feet apart—each grew equally well and produced from ten to fourteen tons of green fodder per acre. The cow-peas twined around the corn-stalks, making the crop easy to harvest with the corn-binder. (See frontispiece.)

PASTURE.

While the cow-pea, because of its general habit of growth, is not a natural pasture plant, few farmers are using it for this purpose. Maturing as it does in the latter part of the summer, the crop furnishes succulent pasture during the time when natural pastures run short. When used with corn to supplement the ration, such pasture can hardly be excelled, especially for hogs and sheep. The stock are usually turned on cow-peas when the crop has reached the stage of maturity considered best for hay, or when some of the pods have begun to turn yellow. Cattle are usually turned on earlier than sheep or hogs; hogs may be pastured on ripe peas. If the stock are turned on the field too early, before the plants have attained full size, there is more waste from the trampling. The plant at this time is more watery and does not furnish its full feeding value. As with many green-pasture crops there is danger of bloat when sheep or cattle are first turned onto cow-peas, yet the danger is far less than with alfalfa, and is lessened as the cow-peas become more mature.

Where cow-peas are to be used for pasture, especially with hogs, it would be preferable to plant with corn. In this way

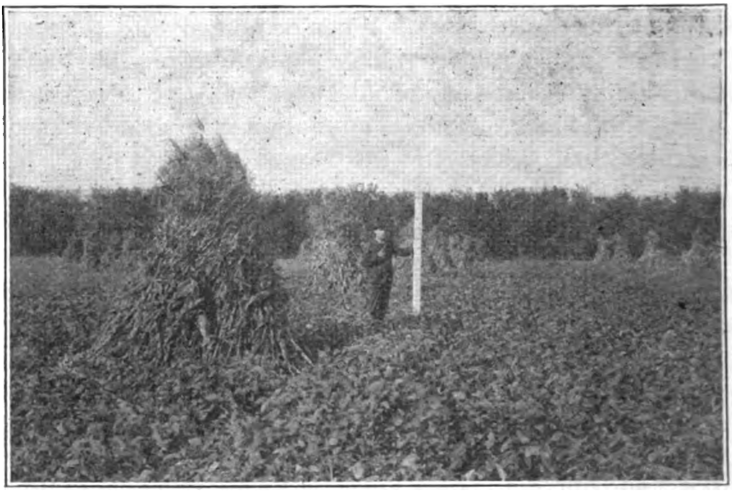

Plate II. Cow-peas planted in corn at the last cultivation.

the mixture makes a ration on which hogs do exceptionally well without other grain. When planted with corn for hogging down, the usual method is to plant the same as for ensilage, taking care not to plant the corn so thick as to stunt the growth of the cow-peas. Another method, and one often practiced in pasturing sheep in the more humid climates, is to plant the cow-peas in the corn between the rows at the last cultivation. At this Station we have planted cow-peas in corn at the last cultivation for a number of seasons, and they usually make a fair growth if there is sufficient moisture, but when the early fall is dry the cow-peas do not make much growth until the corn is mature. There seems to have been no injurious effect on the corn resulting from this practice, but rather in most seasons the result has been an increased yield of corn in fields in which cow-peas have been planted. Table I gives the comparisons and yields for five years of corn planted alone and with cow-peas drilled between the rows at the last cultivation.

TABLE I. Yield of corn per acre, bushels.

How Planted.	1903.	1904.	1905.	1906.	1907.	Average.
Corn alone	23.36	56.57	37.80	64.17	38.01	43.98
Corn with cow-peas, planted at last cultivation	23.13	67.28	45.98	59.89	41.81	47.62

The average for five years shows that corn in which cow-peas were planted produced 3.64 bushels more grain per acre than corn alone. In 1906, which was relatively dry in August and September, the corn with cow-peas yielded 4.28 bushels per acre less than corn alone. In 1903 the yield was slightly in favor of corn alone. For the other three years the yield was greater where the cow-peas were planted with the corn.

In the drier sections of the state, where fall pasture is needed, it would be better to plant the cow-peas in wheat, oats, or barley stubble rather than in corn. When planted after wheat or oats the cow-peas make a much ranker and more rapid growth, are not checked so severely by a dry fall, and will produce in nearly every instance more fall pasture than could possibly be secured by planting in corn. After pasturing, the cow-peas may be turned under in the fall, leaving the ground in excellent condition for corn the following spring.

SOIL IMPROVEMENT AND GREEN MANURING.

The growing of cow-peas greatly improves the soil. Being a rank feeder and deep-rooted, the crop is able to use plant-food which the roots of other plants may not secure. Much of this plant-food later becomes available to other crops planted after the rotation with cow-peas. This crop has the advantage over other crops which are not legumes, in that it is able to use the free nitrogen of the air through the aid of the bacteria which live upon its roots. The plowing under of a crop of green cow-peas will greatly increase the supply of humus and nitrogen in the soil, and even when the crop is harvested for hay or seed some increase in soil nitrogen will result from the decay of the roots left in the soil.

In most soils of this state nitrogen is the limiting element of fertility, and anything that will increase the nitrogen supply of the soil will increase the soil's productiveness. The cow-pea, having this ability to secure nitrogen from the atmosphere, not only produces more abundantly than a crop not having this power, but leaves the soil in better condition for crops which follow.

Mr. H. T. Neilsen, of the United States Department of Agriculture, in Farmers' Bulletin No. 318, in speaking of the effect of the cow-pea upon following crops, says: "The increase in yield of wheat due to the cow-peas is generally given as from three to five bushels per acre. At the Missouri Experiment Station, an increase in yield of 63 per cent. with oats and 49 per cent. with wheat following cow-peas as a catch-crop was secured. The Arkansas Experiment Station reports, as an average of four years' test with wheat, an increase in yield of 25 per cent. from plowing under cow-pea stubble in the fall, 39 per cent. from plowing under cow-pea vines, and 42 per cent. when cow-peas were grown each year as a catch-crop between the wheat crops, only the stubble of the peas being plowed under."

At this Station we have sown cow-peas as a catch-crop between the wheat crops for the past five years, plowing under the entire growth of peas about the middle of September, two or three weeks before seeding to wheat. The cow-peas have been sown each year soon after wheat harvest, in close drills, at the rate of about one bushel of peas per acre. The field was usually double-disked ahead of the drill. Both plots were plowed on the same date and given similar preparation before seeding. The field used for this work was upland soil low in fertility. The yields for the past five years are given in table II.

TABLE II. Yield per acre of wheat.

TREATMENT.	1904.	1905.	1906.	1907.	1908.	Average.
Wheat continuously	13.40	12.02	13.41	11.79	11.08	12.34
Wheat continuously with cow-peas as catch crop	14.49	16.53	15.54	16.37	20.18	16.61

Each season the catch-crop of cow-peas has given an increased yield of wheat and the effect has been accumulative, the increase in yield being gradual from year to year. The first year of the trial there was a difference of only one bushel in favor of the cow-pea rotation, while after five years the plot which received the green manuring produced nine bushels more wheat per acre, the average difference being four and one-third bushels per acre in favor of planting cow-peas as a catch-crop between crops of wheat. In carrying out this test every effort was made to put the seed-bed in as good condition as possible before the wheat was sown. After plowing, the subsurface packer was used and the seed-bed made as firm as possible.

While the effect of the cow-peas in maintaining the fertility of the soil, where used as a catch-crop with wheat, is clearly shown by this experiment, the practice can hardly be recommended in general farming. In the wheat belt of the central and western parts of the state there is not sufficient moisture to produce a crop of cow-peas for green manuring and still

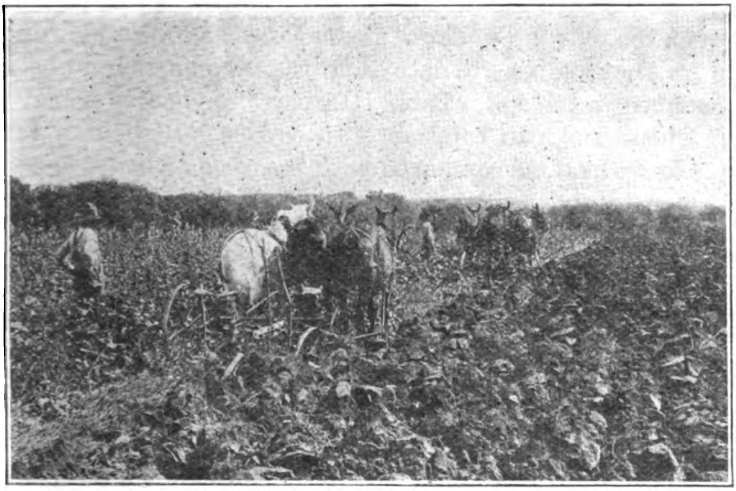

PLATE III. Plowing under cow-peas for green manure, September 21, 1908.

leave the ground in condition for starting the wheat the same fall, except in very favorable seasons. Also, the extra labor involved in preparing a good seed-bed for wheat after cow-peas makes this method unpractical. (Plate III.)

A more practical rotation is to plant cow-peas in wheat or oats stubble, plow the crop down before heavy frost in the fall, and follow with corn the next year. A common practice at this Station is to plant the cow-peas during the wheat harvest, following the binder directly with a single-disk drill; or, if the stubble-land is weedy or trashy, it is advisable to disk ahead of the drill behind the binder, thus preparing a more suitable seed-bed. Thus when the harvest is finished the field has been replanted and, if the extra labor can be supplied, this is an economy of time, and the new crop will have all the advantages which may come by timely rains and favorable growing conditions. If it is not possible to plant during the harvest of the grain, then the cow-peas may be sown as soon as possible after the harvest, preferably disking ahead of the drill between the rows of shocks. Occasionally, by early thrashing, the field may be cleared soon enough to plant the peas, but such planting should not be delayed long after July 1. Planted in this way at this Station, cow-peas have made a growth of twelve to eighteen inches by the last of September, when the crop was plowed under. Such fall-plowed land is in excellent condition for corn the next season, since there is sufficient time between the plowing under of the cow-peas and the planting of corn for the cow-peas to decay and for the moisture to become replenished in the soil. Table III gives the yield of wheat and corn when grown in rotation with cow-peas used as a catch-crop after wheat, as compared with the yields when wheat and corn were grown in rotation without the intermediate green manuring crop of cow-peas.

TABLE III. Yield of corn per acre, bushels.

	1904.	1905.	1906.	1907.	Average.
Following cow-peas used as catch crop after wheat.	44.89	63.55	65.81	37.76	50.75
Following wheat without cow-peas	32.40	44.89	57.57	32.21	41.77

Yield of wheat per acre, bushels, in rotation with corn, second year after cow-peas:

	1904.	1905.	1906.	1907.	Average.
With cow-peas.	17.59	22.53	16.58	9.25	16.49
Without cow-peas.	17.20	18.67	14.74	9.05	14.91

These results show that cow-peas used as green manure have had a remarkable effect in increasing the yield of corn, the average annual increase in yield for the four years being nearly nine bushels per acre; also, there was a small increase (about one and a half bushels per acre) in the wheat crop following the corn the second year after the cow-peas were plowed under. The relatively low yield of wheat on all plots is in part due to the unsuitable seed-bed; the wheat was planted in the corn-stalks each fall.

This seems to be a more practical and successful method of using cow-peas for soil improvement than by growing the peas with corn or sowing them as a catch-crop in continuous wheat culture. Also this is a practical way of maintaining the nitrogen and humus supply of the soil, especially on farms keeping little live stock; but upon a stock farm a green manuring crop should not be expected to replace barn-yard manure but rather to supplement it. Upon stock farms where cow-peas are grown as a catch-crop after wheat or oats for soil improvement it will be found more profitable to pasture the cow-peas rather than to plow the entire crop under. Little of the beneficial effects of the cow-peas is lost by this practice, since by pasturing the droppings of the animals remain upon the field, and even when the cow-peas are cut for hay and fed there may be but little loss of fertilizing elements if care is taken to preserve the manure and return it to the land.

AS A ROTATION CROP.

When grown for seed or forage, cow-peas are a valuable crop to use in rotation with other crops. Preferably cow-peas should be used to precede potatoes, corn, Kafir-corn, cane and other rank-growing forage crops, rather than small grains, since in the more favorable seasons, in fertile soil, small grain is apt to lodge when grown after cow-peas. Also, since cow-peas are harvested late, the soil may be left too dry to start fall wheat well. Rotation experiments carried on at this Station for five years with cow-peas or soy-beans and wheat have given the following results:

Wheat Rotation with Soy-beans or Cow-peas.

Previous crop.	Wheat—yield per acre, bushels. 1904.	1905.	1906.	1907.	1908.	Av.
Wheat (continuously)	17.13	24.40	40.40	37.68	29.53	29.83
Soy-beans or cow-peas (alternate years)........................	21.10	26.54	31.10*	38.03	25.16	28.39

Wheat followed soy-beans in 1904-1906, and cow-peas in 1907-1908.

* Lodged badly, which accounts for lower yield.

The rotation experiments with corn and soy-beans have resulted in increasing the yield of corn after soy-beans, the average annual increase in yield being over fourteen bushels of shelled corn per acre, as an average for four crops. The results are given as follows:

Corn Rotation with Soy-beans.

Previous crop.	Wheat—yield per acre, bushels. 1904.	1905.	1906.	1907.	Av.
Corn (continuously)........................	48.21	53.00	62.44	45.56	52.30
Soy-beans (alternately)........................	58.72	68.26	75.53	63.62	66.53

The straw and stalks invariably made a ranker growth after the cow-peas.

SEED.

Cow-peas are an uncertain crop for seed in this state, as the yield of seed varies greatly from year to year, depending upon weather conditions. When the summer is favorable and hot the yield of seed is quite satisfactory, but when the summer is cool or too wet or too dry, the yield is apt to be low. As shown by the trials at this Station, in favorable seasons, good producing varieties have yielded from fifteen to twenty bushels per acre, while in an unfavorable season the same varieties have produced only from five to seven bushels per acre. This uncertainty of a seed crop makes the cow-pea an undesirable crop to grow in a commercial way for seed production, but the value of the crop for soil improvement, pasture, hay and ensilage, and the high price of the seed upon the market, makes it desirable for every farmer to grow enough cow-peas for seed to supply his own needs. At the present price of seed ($3 per bushel) the average farmer does not feel that he can afford to buy the seed of cow-peas for green manuring, although the expenditure of this amount would doubtless be repaid by the increase in the yield of crops through the increased fertility of the soil. However, if the farmer can raise each year from five to ten acres of cow-peas for seed he will have a supply of seed on hand for his own use, which, in favorable seasons, will have cost him less than one dollar per bushel to produce, and in unfavorable seasons the cost should not be greater than the average market price of good seed peas.

OTHER USES.

Besides the uses for cow-peas discussed above there are a few minor uses for which the crop is sometimes grown. In some of the Southern states where cow-peas seed heavily the seed is grown and used for stock feed. Cow-pea seed has a high feeding value, furnishing about two and a half times as much protein and nearly as much carbohydrates as corn. At the present prices cow-pea seed cannot be profitably grown for feed, but in thrashing more or less of the seed may be broken, making it unfit for planting. Such seed should be ground and fed; mixed with corn-meal or other ground grain it makes especially good feed for hogs or dairy cows. Cow-peas are also used in a small way for human food, prepared in much the same manner as the garden bean.

COW-PEAS COMPARED WITH SOY-BEANS.

In some respects the soy-bean would seem to be a more desirable crop than the cow-pea, and in many sections of the country they grow well and are popular. However, in this state (Kansas) they have not proven as sure a crop as cow-peas. The soy-bean as a rule produces more seed than the cow-pea, the seed ripens more nearly at the same time and is easier to save and thrash, while the stalk, growing upright without vining, makes the crop easier to harvest; also, the hay of the soy-bean when properly saved has a little greater feeding value, being richer in protein. In spite of these qualities favorable to the soy-bean, it is surpassed in three respects by

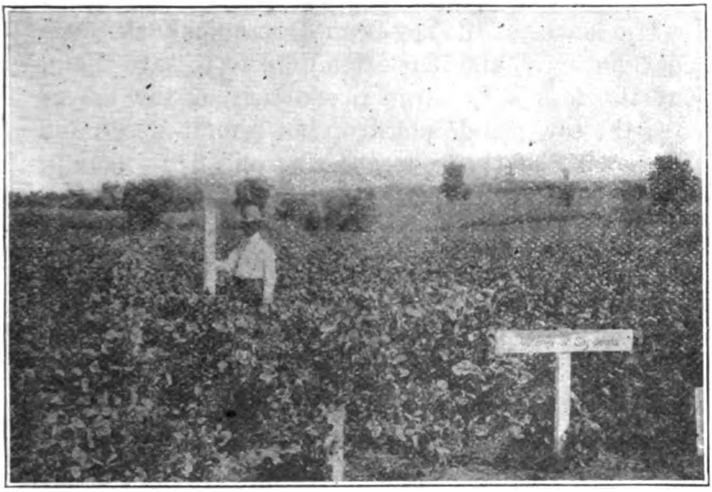

PLATE IV. Varieties of soy-beans, showing upright habit of growth.

the cow-pea, which would seem to make the latter a more desirable crop for this state.

First.—The stand of cow-peas is more certain than the stand of soy-beans. The seed is more sure of germination, perhaps due to the fact that soy-bean seed is more apt to heat in storage. Also the soy-beans fail to come up well if the soil is crusted, while the cow-peas, being a more vigorous grower, push their way out of heavily crusted soil. This ability of the cow-pea to grow under unfavorable conditions and in a poorly prepared seed-bed is very essential, especially when stubbled in after wheat or oats.. The soy-beans when sown in this state on land new to the crop usually require inoculation of the soil or seed before they will thrive well, while the cow-pea seems to find its bacteria in the soil, and will grow well on nearly every soil without inoculation. Rabbits trouble soy-beans more than cow-peas, and this is a very important consideration, especially in western Kansas. These several factors tend to favor a better stand of cow-peas than of soy-beans.

Second.—Cow-peas are better suited for planting with corn than soy-beans. Cow-peas when planted with corn not only produce more forage than soy-beans, but the vining habit of growth of cow-peas causes them to twine around the corn, so that the vines are held up, which makes the combined crop easier to harvest with a corn-binder.

Third.—The cow-pea is better adapted for hay than the soy-bean. The leaves of the soy-bean drop quickly as the crop approaches maturity, and it is often difficult to save the hay crop without the loss of a large proportion of the leaves. The leaves of the cow-pea do not drop but remain green and growing after many of the pods are ripe and dry. Again, if the soy-bean is allowed to become a little too mature, not only is there a loss of leaves in curing but the stems become hard and woody and less palatable to stock. On the other hand, soy-beans are somewhat more readily cured and handled for hay, and as pasture for cattle may excel the cow-peas, since the green soy-beans are apparently better relished by stock. (Plates IV and V.)

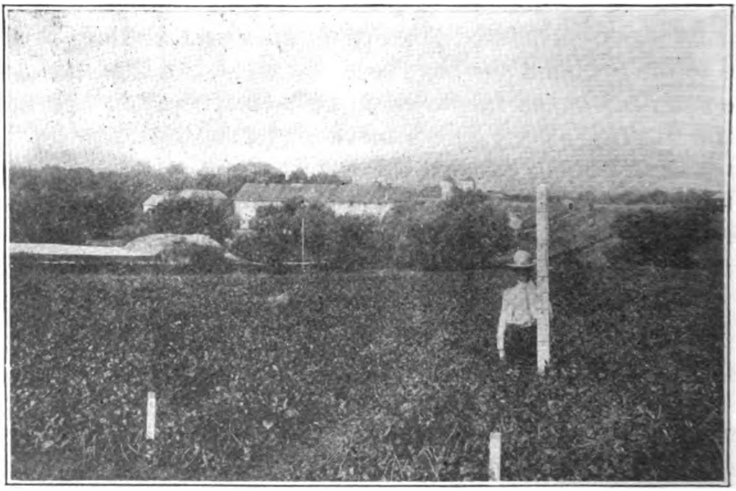

PLATE V. Varieties of cow-peas, showing vining habit of growth.

TABLE IV. Varieties of cow-peas.

Bulletin No.	Name of Variety.	Days to mature	Yield per acre.											Av. yield pr. acre.	
			1903.		1904.		1905.		1906.		1907.		1908.	1903-'07.	1903-'08.
			Grain.	Hay.	Grain.	Hay.	Grain.	Hay.	Grain.	Hay.	Grain.	Hay.	Hay.	Grain.	Hay.
			bu.	*tons.*	*bu.*	*tons.*	*bu.*	*tons.*	*bu.*	*tons.*	*bu.*	*tons.*	*tons.*	*bu.*	*tons.*
118	Mount Olive	114	7.24	1.72	14.96	6.35	11.60	2.05	15.00	1.65	4.86	2.84	1.47	10.73	2.68
65	Whippoorwill	111	6.23	1.38	14.25	6.25	16.52	2.79	12.77	1.76	7.54	1.98	1.59	11.46	2.63
271	Gray Goose or Taylor	113	2.74	2.12	23.31	3.32	15.87	2.78	15.62	2.54	1.78	2.21	1.85	11.86	2.47
202	Hammond's Black	114	6.10	1.84	17.73	2.78	16.08	2.05	8.32	2.49	7.46	2.27	1.97	11.13	2.23
277	Black Eye	111	8.00	1.66	19.78	3.28	16.33	2.05	12.37	2.68	7.05	1.40	1.97	12.71	2.17
183	New Era	107	11.07	.86	18.86	3.75	12.03	2.57	15.62	2.14	4.62	2.53	.97	12.44	2.14
188	Michigan Favorite	107	7.62	1.16	17.94	2.80	12.40	3.14	14.40	1.85	3.81	1.88	1.75	11.23	2.10
274	Warren's New Hybrid	107	6.56	1.78	21.11	3.45	12.76	2.13	18.85	1.50	8.02	2.13	1.37	13.46	2.06
270	Old Man's	108	9.10	1.82	20.97	2.90	12.91	2.17	9.12	1.86	5.35	2.38	1.05	11.49	2.03
121	White Giant	108	8.62	1.22	17.57	4.88	16.42	1.45	9.33	1.16	2.11	1.78	1.23	10.81	1.95
279	Clay	108	1.09	1.97	16.04	3.17	13.85	....	15.20	1.53	8.10	1.59	1.45	10.86	1.94
273	Warren's Extra Early	107	4.21	1.40	17.72	3.15	10.06	1.97	18.45	2.37	3.57	1.45	.87	10.80	1.87
	Varieties of soy-beans.														
343	Early Yellow	99	14.80	....	20.10	1.96	10.18	1.69	13.18	3.01	5.59	1.54	1.31	12.77	1.90
326	Ito San	102	14.80	....	16.53	1.77	10.13	1.58	13.68	1.85	10.59	2.34	1.54	13.15	1.81
335	Small Yellow	109	15.80	....	16.89	1.95	16.38	1.09	14.80	2.29	9.61	1.67	1.61	14.71	1.72
333	Green Samarow	105	14.50	....	13.59	1.94	11.67	1.09	12.98	1.75	....	1.28	.99	13.18	1.41

VARIETIES OF COW-PEAS.

During the past six years some forty varieties of cow-peas and thirty-five varieties of soy-beans have been tested by the Station for seed and hay production. Some of these varieties have been grown but one year, many of them showing good qualities have been grown two or more years, while the most promising varieties have been grown throughout the six years. Table IV gives the yield of different varieties which have been grown for the entire six years, arranged in the order of hay production. (See page 191.)

These varieties, being selected as the most productive from the forty varieties tested, do not show striking variations in yield. The Mount Olive ranks first, having produced an average of 2.68 tons of hay per acre for the six years, and Whippoorwill second, having produced an average of 2.63 tons of hay per acre. In the production of seed for an average of five years, 1903 to 1907, inclusive, the Warren's New Hybrid has produced the largest yield, 13.46 bushels per acre; Black Eye second, 12.71 bushels, and New Era third, 12.44 bushels.

For the production of cow-pea seed four characteristics are especially desirable, namely, yield, evenness of ripening, early maturity, and an upright habit of growth. The New Era seems to have these characteristics the most highly developed. It is a good yielder of both hay and seed; is as early and as evenly maturing as any good variety, ripening in 107 days; and has the most upright habit of growth of any of the varieties reported, thus making it the most easily harvested. Mount Olive, which leads in hay production, matures later and produces less seed. Hammond's Black, also a good hay producer, cannot be depended upon to mature seed. The Whippoorwill is a little late in maturing, but it is a high-yielding variety and is especially adapted for growing with corn for ensilage, as it has a twining habit of growth and ripens well with varieties of corn like Silvermine, Boone County White, Legal Tender and Reid's Yellow Dent. White Giant cannot be recommended, since it is troubled greatly by blight, which often nearly ruins the crop. Judging from these tests the following varieties may be recommended for growing in this state: For seed, Black Eye, New Era, Warren's New Hybrid; for hay, Whippoorwill; for a catch-crop after wheat, New Era.

The following varieties of cow-peas have been grown one or more years at this Station, but for various reasons have not proven so well adapted to our conditions as other varieties named above: Extra Early, Unknown or Wonderful, Iron, Black, Red Unknown, California, Red River, Yellow Sugar, Chowder, Extra Early Black Eye, Large Black Eye, and Lady or Galivant. The following varieties of soy-beans have also been tested one or more years: Green, Medium Green, Olive Medium, Ogema, Extra Early Black, Early Green, Flat Black, Early Black, Medium Early, Green, Yellow, Southern, Large Yellow, Late Yellow, Medium Yellow, Green Black, and Large Medium Late Yellow.

CULTURE OF COW-PEAS.

SOIL.

There is no more metropolitan crop grown in the corn belt than the cow-pea. It will grow and make profitable crops on nearly every type of soil in the state of Kansas when supplied with the necessary amount of moisture and given good culture. The plant is better adapted to the open soils of a sandy loam nature rather than to the clay loams or heavy clays. These more open soils allow good aeration, which favors bacterial activity and thus promotes a better development of the plant. The heavy clay soil produces but a small crop the first year, but the second year the crop grows better, which probably results from the soil being opened and enlivened by the deep root system of this plant. The deep rooting of the cow-pea in soils of this character puts these soils in better condition for all classes of crops which may follow the cow-peas.

The cow-pea is everywhere recognized as a rank feeder, being able to extract plant-food from soils almost barren to other crops, thus making it well adapted for growing on "worn-out" soils as a soil renewer. It has an especial advantage over some other leguminous crops in being able to grow from the start upon new land without inoculation with the bacteria which live upon its roots and which aid it in securing nitrogen from the atmosphere. Whether these bacteria are always present in sufficient numbers in soils new to the crop, or whether the bacteria adhere to the seeds and are thus carried to the soil with the seed, has not been proven. Tubercles may nearly always be found upon the roots of cow-pea plants the first season the crop is grown on new land. This habit gives the cow-pea an advantage over the soy-bean, since new fields must usually be inoculated with the soy-bean bacteria before the crop will thrive. Also, the presence of these nitrogen-gathering bacteria is required in order that the legume crop may store nitrogen and improve the fertility of the soil.

A soil of medium fertility is considered best for the production of cow-peas. On poor soil the plants produce a light yield of hay, although often seeding well. Upon a very fertile soil there is apt to be an excessive growth of vines which fail to produce seed well and which are difficult to cure for hay. Cow-peas, like other legumes, will not grow well in a wet soil; nor are they particularly well adapted for dry farming, unless given very careful culture. They will grow wherever corn will grow successfully. For the drier portions of the state the earlier-ripening varieties are to be preferred.

PREPARATION OF SOIL.

While the cow-pea will grow upon a poorly prepared seed-bed it responds to good cultural methods. The seed-bed for cow-peas should receive as careful preparation as the seed-bed for corn. Although cow-peas are necessarily planted late in the spring, it is often desirable to plow the ground early and cultivate the field at intervals with the disk or harrow to destroy weeds and maintain a soil mulch to receive and retain the moisture. It is advisable to plow in the fall or winter certain types of heavy soil not inclined to drift, or land which has no cover of stubble or stalks. Such land may be disked and harrowed in the spring to clear it of weeds and put it in good condition for planting.

When seeded as a catch-crop after wheat or other small grain, the most practical method is to prepare a seed-bed with the disk-harrow, or to seed with a single-disk drill without previous cultivation, if the ground is clean and mellow. Plowing the ground at this time would put it in condition to hold more moisture and might give a greater growth and a more perfect stand of peas, but in order to plow wheat or oat stubble it would often be necessary to wait until after thrashing, which

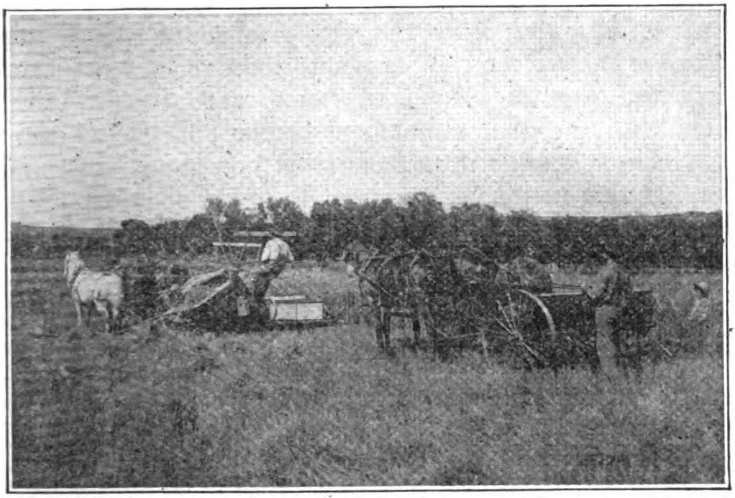

Plate VI. Planting cow-peas in wheat stubble immediately following the binder, with a single-disk drill.

in most instances would mean planting too late to insure a good stand and good growth of cow-peas. Unless the stubble is disked behind the binder the amount of moisture lost before plowing would often more than offset the gain from a mellow condition of the surface soil secured by plowing. In planting cow-peas after small grain as a catch-crop at this Station, we have found it advisable to follow the binder immediately with the disk-harrow and the disk-harrow immediately with the disk-drill. This practice means a rush of work, but by this method the work of seeding does not interfere with the shocking of the grain and the peas are planted at the earliest possible date. The crop so planted has every advantage of rainfall and favorable conditions for growth. The moist, mellow condition of the soil usual at harvest-time insures a rapid germination of the peas, while if the preparation and planting is delayed a few days the ground is apt to dry out and become hard. This practice can only be followed upon reasonably clean stubble land. (Plate VI.)

METHODS OF PLANTING.

The method of planting cow-peas will depend upon the purpose for which the crop is grown. For the production of seed, the best practice is to plant in rows about three feet apart, dropping the peas in the rows two or three inches apart. A common corn-planter may be used for this purpose, but the rows will be farther apart than is necessary for the greatest production of peas. With the edge-drop planter, it is necessary to use the sixteen-cell plate and the highest gear in order to drop the peas thick enough. Some farmers use the corn-planter with the drill attachment, straddling each alternate row, which makes the rows from twenty to twenty-two inches apart. If this method is followed the peas should be placed about six inches apart in the row. Rows placed too close together are inconvenient for cultivating. A good method of planting practiced at this Station is to use a common grain-drill which will not split the peas (there is a difference in drills in this respect), stopping up part of the grain cups so as to leave the rows about three feet apart, setting the drill to sow about two bushels of wheat per acre. This rate of seeding drops the peas about two to four inches apart in the row and requires ten to twelve quarts of peas to seed an acre. The peas should be planted two to three inches deep in mellow soil.

The usual practice is to surface-plant cow-peas. They may, however, be successfully planted in furrows, either by listing or preferably by the use of the furrow-opener on the corn-planter. At this Station the usual plan is to plant with the furrow-openers. There may be advantage from furrow planting by getting the peas deeper in dry soil. In early cultivation the weeds are more readily destroyed by covering them as the furrow is filled. If cow-peas are listed care should be taken not to list over four or five inches deep. The plants start slowly in a deep-listed furrow and usually make a poor stand and a dwarf growth.

When the cow-peas are planted for hay or green manuring, the best method is to sow broadcast or in drill-rows six to eight inches apart. For planting in this manner the grain-drill will prove the most satisfactory implement, and should be set to sow about six pecks of wheat per acre, which will sow the peas at the rate of a bushel to one and a half bushels per acre. Planting in close drill-rows does not require later interculture. The peas do not vine so much, grow more upright, are easy to harvest with the mower, and make a less woody hay.

When planted for ensilage with corn the most successful method is that of planting the corn and cow-peas at one operation. The common two-row corn-planter, with the sixteen-cell edge-drop plate, in which the notches have been filed out to make the cells as large as possible, may be used. The cow-peas and corn should be mixed about half and half by weight and the planter set with the drill attachment to plant as thickly as possible. This gives the proper stand of the combination crop, corn averaging about eighteen inches apart and cow-peas four to six inches apart in the drill-rows. If the corn is planted much thicker than suggested a rank growth of stalk is apt to smother the cow-peas, while if the corn is too thin the stalks fail to support the cow-pea vines, making the crop difficult to harvest.

When cow-peas are sown in corn at the last cultivation the usual method is to sow with the one-horse wheat-drill, planting two or three rows of peas between the rows of corn. A common practice also is to sow the peas broadcast in the corn at the last cultivation and cover them with the cultivator. This method is not so satisfactory, on account of the unevenness of the depth of covering and the consequent poorer stand of peas which may result. (Plates II and VII.)

TIME OF PLANTING.

Cow-peas, being a southern crop, are naturally sensitive to cold. When planted in cold, wet soil, the seed will either rot or the plants will make a poor, sickly growth. Cow-peas should not be planted until the soil has thoroughly warmed up and not until all danger of periods of cold weather has passed. Cold spells shortly after planting will often cause a poor stand of the peas. The time of planting will depend largely upon the purpose for which the peas are grown. For green manuring they may be sown as late as the last of July and will make a considerable growth of green material to be plowed under before frost, but if planted for hay or seed it is necessary to sow earlier. In order to determine the most satisfactory date at which to plant cow-peas, an experiment was started in 1904, planting cow-peas at different dates. This experiment was continued through 1905 and 1906. The results are shown in table V.

In this experiment the New Era, one of the earliest maturing varieties of cow-peas, was planted. Since the dates of planting in 1904 do not exactly correspond with those of 1905 and 1906, the yields of the 1904 crop have not been used in de-

TABLE V. Date to plant cow-peas—a summary of results for three seasons, 1904, 1905, 1906.

DATE PLANTED.	Yield per acre.						Average yield per acre for two years' trial, 1905–'06.	
	1904.		1905.		1906.			
	Hay.	Grain.	Hay.	Grain.	Hay.	Grain.	Hay.	Grain.
	tons.	*bu.*	*tons.*	*bu.*	*tons.*	*bu.*	*tons.*	*bu.*
May 12	....	....	0.87	3.93	1.51	10.39	1.19	7.16
May 19	2.01	15.92	1.61	7.77	2.39	12.88	2.00	10.32
May 26	3.55	17.93	1.85	8.98	2.15	10.85	2.00	9.91
June 3	4.00	19.90	2.32	11.20	2.20	10.14	2.26	10.68
June 9	....	....	2.57	12.08	1.60	11.15	2.08	11.59
June 16	3.76	23.81	1.82	5.85	1.73	6.08	1.77	5.96
June 28	2.23	22.89*	1.21	5.75*	1.00	3.20	1.10	4.47
July 14	1.92	0.00*	....	....	....	....	....	....

* Injured by frost.

termining the average. Taking the average yields for 1905 and 1906, we find that planting June 9 has given the highest yield of grain, and planting June 3 has given the largest production of hay. In 1904 the greatest yield of hay was produced from the June 3 planting, but for this season the later seedings of June 16 and 28 gave the largest production of grain. In 1905 the June 28 planting was injured by frost and in 1904 the July 14 planting was killed by frost, so that no seed matured. This experiment shows that it would not be a safe practice to plant New Era cow-peas for seed later than the 25th of June, and that the best results year after year will probably be obtained by planting from the 25th of May to the 10th of June. For the largest production of hay the cow-peas should be planted a week earlier. The early planting of the peas usually causes a heavy growth of vine and a decreased production of seed. It is a safe practice not to plant until about two to three weeks after the regular corn-planting time.

When planting cow-peas with corn for ensilage our experiments at this Station indicate that the best time for planting the combination crop is about the first week in June. If planted earlier than this, when the soil is cold, the cow-peas start slowly and are thus apt to be covered and destroyed by the early cultivation of the corn, or the corn, starting more rapidly, outgrows the cow-peas which make only a dwarf growth. If, however, the ground is permitted to warm up

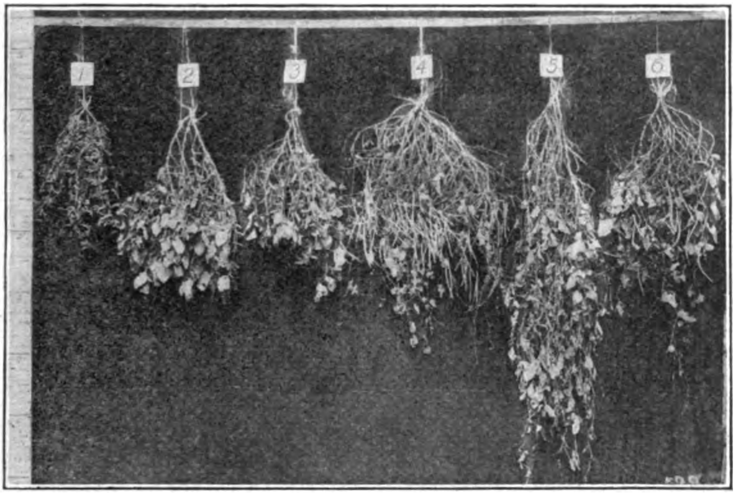

PLATE VII. Individual plants of cow-peas and soy-beans. No. 1, Early Yellow soy-bean; No. 2, Southern soy-bean; No. 3, Flat Black soy-bean; No. 4, New Era cow-peas; No. 5, Clay cow-peas; No. 6, Whippoorwill cow-peas.

before the combined crop is planted, the corn and cow-peas start together and grow equally well.

CULTIVATION.

If the soil is sufficiently warm when the cow-peas are planted the plants will start quickly and grow rapidly. When planted in rows for seed, the crop may be cultivated in two or three weeks after planting. Unlike corn, the young cow-pea plants are tender and should not be cultivated with the weeder or harrow; at least not until the plants have made some growth and are not so easily broken. If the peas are planted in furrows the crop may be harrowed during its early growth without injury to the young plants. It sometimes happens that a heavy rainfall soon after the seeding of cow-peas causes the soil to become crusted, making it difficult for the young plants to push their way out. In this condition a harrow may be used to advantage to break the crust without much danger of injury to the sprouting plants.

When cow-peas are sown broadcast they require little or no cultivation after they are out of the ground. If the ground was well cultivated and cleaned of weeds previous to seeding, the young plants with favorable weather grow rapidly and will usually smother any weeds which may start after the planting. When planted in rows the crop should be cultivated in about the same manner as corn. Three cultivations with the cultivator are usually all that are required. It is perhaps preferable to cultivate the first time with the knife or Acme cultivator, which may be run close to the row without much danger of covering the plants. For the second and third cultivation, the six-shovel cultivator is preferred. For seed production, cow-peas should be cultivated the last time just before blooming. Very little is gained by later cultivation, as it causes greater vining of the plant and thus later maturity.

HARVESTING COW-PEAS.

FOR HAY.

Cow-peas should be cut for hay when most of the pods are developed and when the first pods and some leaves begin to turn yellow. At this stage the plant has attained its growth and none of the leaves have been lost. If cut before maturity the vines are watery and difficult to cure, while if left too late before cutting there will be an unnecessary loss of leaves in handling and the stems will be tougher and more woody. Cow-pea hay should be handled in curing in about the same manner as alfalfa, but it cures more slowly than alfalfa. A good practice is to begin cutting in the morning as soon as the dew is off when the indications are for favorable weather for a number of days. Before the leaves have become very dry the hay should be raked and allowed to cure in the windrow a short time. It should then be placed in cocks of moderate size, made as high in proportion to circumference as possible. The cocked hay should be allowed to remain in the field for three or four days until the stems of the peas are well cured, when the hay may be mowed or stacked. Where possible, cow-pea hay should be stored under shelter. The coarse nature of the forage makes it hard to keep in the stack, since it does not shed water readily.

FOR ENSILAGE.

When sown alone cow-peas should be harvested for ensilage at about the same stage of maturity as for hay. They should be cut only a short time before they are hauled to the silo; should be raked green, placed in small bunches or loaded onto the wagons directly from the windrow. When cow-peas are planted with corn for ensilage, the combined crop may be har-

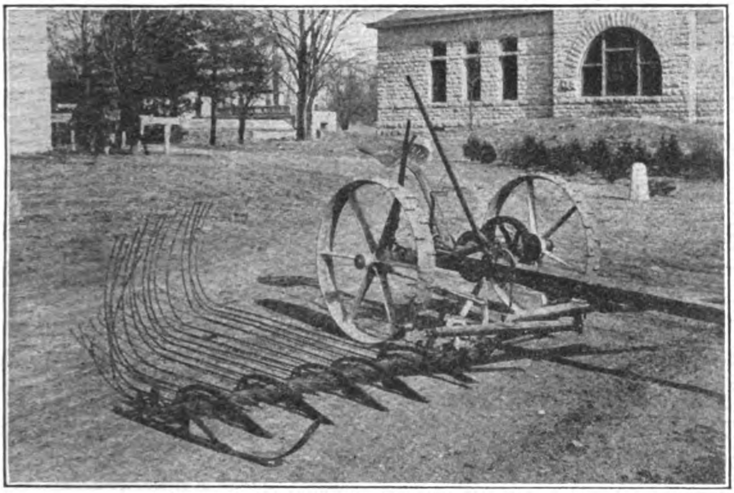

PLATE VIII. Cow-pea harvester attachment for the mowing-machine, showing the vine-lifters on guards, and windrowing attachment.

vested with the corn-binder and handled in the same manner and as easily as corn planted alone for ensilage.

FOR SEED.

Cow-peas ripen so unevenly that it is difficult to judge at just what stage of maturity to cut for seed. With most varieties blossoms, green pods and ripe peas occur at the same time, and this condition continues usually until frost. Harvest before a heavy frost or when most of the pods are brown and the larger proportion of the peas are ripe.

In some of the Southern states, where labor is cheaper, the peas are picked by hand for seed as they ripen. On account of the scarcity of labor in this state this method is hardly practical, although where labor can be secured peas may be picked by hand and thrashed for about one dollar a bushel.

There are several makes of bean- and pea-picking machines manufactured and sold upon the market to-day, but they are not extensively used and it is doubtful if they could be successfully used in this climate, where the peas could not be allowed to complete ripening before picking. A method of harvesting cow-peas for seed is to pull the vines by hand, place in small shocks, and leave in the field until well cured. The peas may be thrashed directly as hauled from the field or they may be stacked and thrashed later. The vines often pull hard, thus it is the practice at this Station to cut them with a straight corn-knife. This method of harvesting is slow and may not be practical where the peas are raised on a large scale, but upon a small scale it is the most satisfactory method. A man should harvest and shock by hand about one-half acre of peas in a day.

The difficulty in harvesting cow-peas by machinery is due to the twining habit of the plant, which causes it to run and entwine together from row to row. The mowing-machine with vine-lifters attached to the guards may be used in harvesting the cow-peas for seed, but one objection to the mowing-machine lies in the fact that the machine and horses have to pass over the peas while in the swath, which shells them badly. To avoid this a bunching or windrowing attachment has been manufactured to attach to the cutter-bar of the mowing-machine, which lifts the cow-peas as they are cut off by the mower and carries them to one side, leaving them directly behind and out of the way of the mower on the next round. If a rolling-colter is used on the end of the cutter-bar to cut off the vines that entwine with the vines of the uncut row, this attachment may give satisfactory results, although the attachment is heavy and is hard upon the mowing-machine upon which it is used. The self-rake reaper has been used in harvesting peas for seed, and is quite satisfactory.

There are several types of bean-harvesters manufactured which are sometimes used in harvesting cow-peas. The most successful of these harvesters are constructed so that two long knives run under the vines cutting off the stems of the peas beneath the surface of the ground. These machines will harvest two rows of peas at a time and leave the vines thrown together in one windrow. With this harvester it is necessary to have rolling-colters placed outside the knives to cut off the vines to prevent them dragging and clogging the machine. This machine has proven very satisfactory for harvesting soybeans, but the cow-peas clog some, and the horses walking ahead of the machine, although walking between the rows, trample some of the vines and shell the peas. When cut with the bean-harvester the peas are thrown into a fair-sized windrow, where they may be allowed to partially cure. One day in the windrow is usually sufficient. The peas should then be placed in shocks and allowed to thoroughly cure. Three or four days of good drying weather will usually cure them suffi-

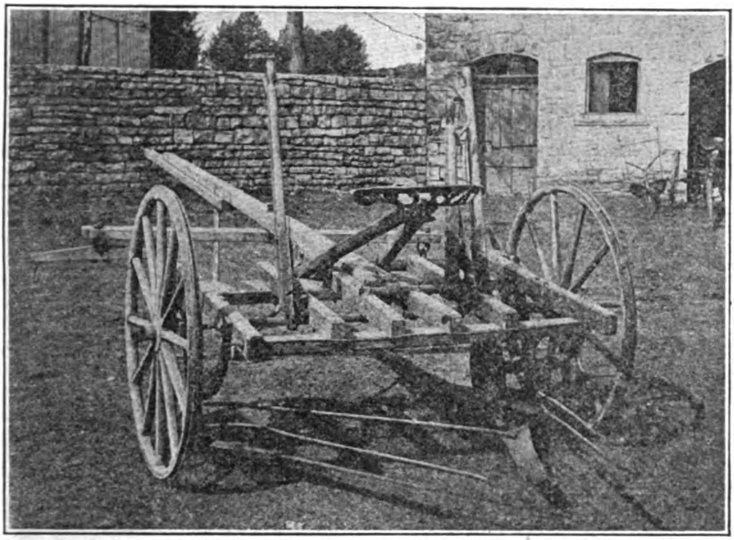

PLATE IX. Bean-harvester, with rolling-colter attached for harvesting cow-peas.

ciently in the shock so that they can be mowed or stacked. Since cow-pea hay takes water very easily, the stacks should be provided with some form of covering. The usual covering, and one that is very satisfactory, is wild grass or prairie hay. (Plates VIII and IX.)

THRASHING COW-PEAS.

When a few acres of cow-peas are grown for seed the most satisfactory method of thrashing is with the flail. This method is slow, yet one man can flail out about an acre of peas in a day, and the work may be done when other work on the farm is slack. Flailing out cow-peas will cost about eight to ten cents per bushel when the seed crop is good, and may cost as much as twenty-five cents when the crop is poor. Cow-pea hullers are manufactured and sold upon the market at prices ranging from $300 to $600, exclusive of the engine. These hullers are reported as doing satisfactory work, although none have been tried at this Station. When enough cow-peas are raised in a neighborhood to justify the purchase of a huller this is undoubtedly the most satisfactory method of thrashing, and when peas are stacked or stored in the barn one machine should be able to thrash 1500 to 2000 acres in a season.

The common thrashing-machine is sometimes used for thrashing cow-peas, but unless adjustments are made to adapt it to thrashing cow-peas it will split more than half of the peas, ruining them for seed. Different thrashing-machine companies make attachments for the common grain-separator to adjust it for thrashing peas and beans, but the trials of such attachments at this Station have not proven successful; either the cow-peas were not thrashed clean or else the seed was badly broken.

Our farm foreman, Mr. Floyd Howard, has made adjustments to the bean-thrasher attachment for the Avery separator so that we were able to thrash cow-peas this past season fairly clean and with no more cracking of the peas than would occur by flailing. Determinations of cracked peas of average samples of the different varieties as they came from the separator showed that the percentage of peas cracked ranged from 3 to 12 per cent. The varieties having the largest sized seed, like the Gray Goose, were cracked the most, while the varieties having smaller seed, like the New Era and Whippoorwill, were cracked the least.

The attachment adjusting the Avery separator for thrashing cow-peas reduces the speed of the cylinder and at the same time maintains the speed of the rest of the machine. To accomplish this the speed of the engine is reduced so as to turn the cylinder at the rate of 500 revolutions per minute (the usual rate for thrashing wheat and oats being from 1000 to 1200 revolutions per minute). In order not to reduce the rate of movement of the rest of the machine it is necessary to increase the size of the pulleys that run the feeder, fanning riddles, cleaning pans, wind stacker, etc. The pulleys were changed as follows: Feeder, from 5½ inches to 12 inches; crank-shaft, which runs the riddles, shaker, grain pan, etc., from 5½ to 12 inches; wind stacker, from 7 to 12 inches. By these adjustments the speed of the separator, except the cylinder, was maintained. All of the cylinder teeth and two rows of concaves were left in the machine, for when any of these were taken out the peas were not thrashed clean. The above changes are included in the regular attachment furnished by the company. It was found, however, that the peas were split badly with the machine thus adjusted, and we were not able to do satisfactory work until Mr. Howard observed that most of the peas were cracked in passing through the grating of iron bars directly behind the cylinder. This grating was removed and replaced by No. 8 wire strung from two to three inches apart and attached at the top and bottom to the bars that originally held the grating. With this adjustment we are able to thrash cow-peas successfully with our Avery separator.

STORING COW-PEA SEED.

Cow-pea seed can be stored for considerable time in this climate without much danger of loss of vitality. The soy-bean is difficult to keep in storage in large quantities, as the seed frequently heats badly. However, this is not the case with the cow-pea, and there is little danger of heating if the peas are sufficiently cured in the mow or stack before thrashing. Cow-pea seed, however, is subject to attack from insects, and especially from the cow-pea weevil, a beetle dark brown in color and about one-fifth of an inch long, that lays its eggs upon the newly formed pods in the field. These eggs hatch and the larva eats through the pod and enters the nearest pea. The insect usually lives within the pea until after the pea is thrashed and placed in storage, when with a suitably warm temperature it comes out of the pea as a mature beetle and lays its eggs upon other stored seed. These eggs soon hatch and produce other larvæ, which cause further destruction of the peas. There may be several generations of these beetles in a single year, so that, unless precautions are taken to destroy the insect as soon as possible after the peas are placed in storage, a large proportion, if not all, of the peas may be infested. Peas infested with weevil can readily be discovered by throwing them lightly into water, when the infested peas will float.

Dr. T. J. Headlee, entomologist of this Station, in speaking of the pea weevil, says that these insects are so easily kept under control that no grower should lose a large amount of seed as a result of their work. He recommends as a preventive measure that the infected seed peas be treated with carbon bisulfid as soon as placed in storage, followed with a second treatment two or three weeks later, when any eggs not hatched at the time of the first treatment will have hatched and may thus be destroyed.

Carbon bisulfid costs about twenty cents a pound, and that

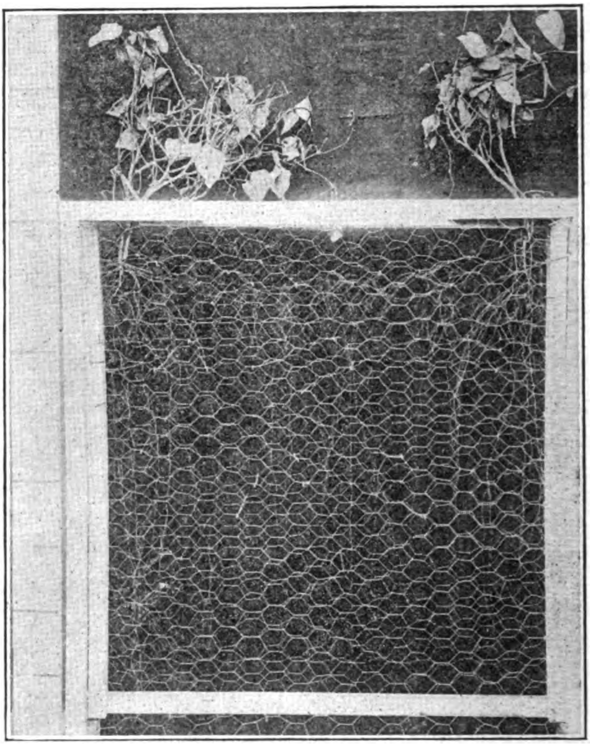

PLATE X. Showing root system of cow-peas 111 days after planting. Plants from adjacent rows three feet apart.

amount is sufficient to treat about 500 cubic feet of peas. The treatment is easily made if the peas are stored in bins as nearly air-tight on sides and bottom as possible. The carbon bisulfid should be placed in a dish on top of the seed, where it will evaporate, and, being heavier than air, will sink into the mass of the seed, destroying any insects present. The gas diffuses equally in all directions through the seed and the quantity of carbon bisulfid to be used must be determined by the total size of the bin. There is no danger of using too much of the liquid. A canvas covering may be thrown over the surface of the peas to insure a more perfect confinement of the gas during the treatment.

Caution.—Great care is necessary in using carbon bisulfid. It is a highly inflammable gas, and no fire of any nature should be allowed in the building where the gas is being used. Care must be taken not to enter the building with a lighted lantern, pipe or cigar until after the building has been thoroughly aired. It is usually best to fumigate seeds with carbon bisulfid in a granary or shed removed some distance from other large buildings, but with proper precautions the fumigating may be done in any building.

SUMMARY.

1. The cow-pea is a leguminous crop enabled by the bacteria that live upon its roots to make use of the nitrogen of the atmosphere and store it in the soil for the use of non-leguminous crops like wheat and corn.
2. Cow-peas make nutritious hay relished by nearly all classes of stock, but the plant is a rank grower and the hay is somewhat difficult to cure.
3. Cow-peas planted with corn make ensilage of higher feeding value than corn alone, being richer in protein. Cow-peas planted with corn produce as much ensilage per acre as may be produced by corn alone.
4. Cow-peas planted with corn at the last cultivation increased the yield of corn in which the cow-peas were planted by more than three and one-half bushels per acre as an average for five years.
5. Cow-peas planted as a catch-crop between crops of wheat in continuous wheat growing increased the yield of wheat four and one-third bushels per acre as an average for five years. Where cow-peas were used the yield of wheat has continually increased. Where not used the yield of wheat has continually decreased.
6. Cow-peas used as a catch-crop after wheat in rotation of wheat and corn increased the yield of corn over nine bushels per acre as an average for four years.
7. Cow-peas have proven a better crop than soy-beans. They are more sure of making a stand, make a ranker growth and larger yield of forage, and are better suited for planting with corn for ensilage and for green manuring than soy-beans.
8. The following varieties of cow-peas have given the best results: For hay, Whippoorwill, Mount Olive, New Era, and Gray Goose; for ensilage, Whippoorwill; for a catch-crop after wheat, New Era.
9. Cow-peas will grow upon a poorly prepared seed-bed, but they respond to good cultural methods, and a seed-bed for

cow-peas should be prepared as carefully as a seed-bed for corn.

10. When sown broadcast or in close drills cow-peas do not require cultivation, but when sown in rows for seed they should be cultivated in about the same manner as corn. Nothing is gained by cultivating cow-peas after the blooming period for seed production, since the late cultivation produces a more vining growth and delays maturity.

11. The best method of planting cow-peas is with a common grain-drill, letting all seed-cups run when planting for hay and stopping up enough of the cups to plant in rows about three feet apart when planting for seed.

12. The best time for planting cow-peas in central Kansas is from May 25 to June 10 for seed, and about one week earlier than this for hay. When planting with corn for ensilage the combined crop planted about June 1 has given the best results.

13. Cow-peas should be cut for hay when the first pods and some of the leaves are turning yellow. For seed the crop should be cut when most of the pods are mature.

14. Cow-peas can be harvested for seed, in a small way, by hand; but when grown in large areas the bean-harvester and cow-pea attachment to the mowing-machine may be used.

15. With the flail is the most satisfactory way of thrashing cow-peas unless they are grown in areas large enough to justify the purchase of a pea-huller or a cow-pea attachment to the grain-separator.

16. The cow-pea weevil which attacks cow-peas in storage can be held in check by treating the stored peas with carbon bisulfid.

ACKNOWLEDGMENTS.

This bulletin has been largely prepared and written by L. E. Call, while several assistants in this department have been concerned with the experiments referred to, as follows: V. M. Shoesmith, now of the Ohio State University; M. D. Snodgrass, in charge of the Experiment Station, Kodiak, Alaska; E. G. Schaffer, present assistant in field crops, and Floyd Howard, farm foreman.

MANUFACTURERS OF COW-PEA MACHINERY.

Bean- and Pea-harvesters.

C. H. Bidwell Thresher Co.,
Batavia, N. Y.

Howland Manufacturing Co.,
Pontiac, Mich.

Lehr Agricultural Co.,
Fremont, Ohio.

Sterling Manufacturing Co.,
Sterling, Ill.

J. S. Rowell Manufacturing Co.,
Beaver Dam, Wis.

Le Roy Plow Co.,
Le Roy, N. Y.

Cardwell Machine Co.,
Richmond, Va.

Ohio Cultivator Co.,
Belleview, Ohio.

American Harrow Co.,
Detroit, Mich.

Reed Manufacturing Co.,
Kalamazoo, Mich.

Gale Manufacturing Co.,
Albion, Mich.

Akron Cultivator Co.,
Akron, Ohio.

Caledonia Bean Harvester Co.,
Caledonia, N. Y.

Thomas G. Gordon Co.,
Elizabeth City, N. C.

Thorp & Sexton Co.,
Salisbury, Md.

Nettleship Bros.,
Fayetteville, Ark.

Bean-hullers.

J. L. Owens Co.,
Minneapolis, Minn.

Engelberg Huller Co.,
Syracuse, N. Y.

Bean-pickers.

A. T. Ferrill & Co.,
Saginaw, Mich.

Miller Bros.,
Rochester, Mich.

Nettleship Bros.,
Fayetteville, Ark.

Bean- and Pea-rakers.

Ohio Rake Co.,
Dayton, Ohio.

Dain Manufacturing Co.,
Ottumwa, Iowa.

Sandwich Manufacturing Co.,
Sandwich, Ill.

Sterling Manufacturing Co.,
Sterling, Ill.

Bean-separators and Graders.

Bacon Manufacturing Co.,
Pontiac, Mich.

Smith Manufacturing Co.,
Valois, N. Y.

A. T. Ferrill Co.,
Saginaw, Mich.

Bean-cleaners.

A. P. Dickey Manufacturing Co.,
Racine, Wis.

A. F. Ferrill Manufacturing Co.,
Saginaw, Mich.

J. L. Owens Manufacturing Co.,
Minneapolis, Minn.

Johnson & Field M'f'g Co.,
Racine, Wis.

Bean- and Pea-drills.

Bacon Manufacturing Co.,
Pontiac, Mich.

Campbell Corn Drill Co.,
Harrison, Ohio.

Keystone Farm Machine Co.,
York, Pa.

Deere & Mansur Co.,
Moline, Ill.

Two-row Bean-planters.

Deere & Mansur Co.,
Moline, Ill.

Moline Plow Co.,
Moline, Ill.

Parlin & Orendorff Co.,
Moline, Ill.

Ohio Rake Co.,
Dayton, Ohio.

NOTE.

The machines manufactured by the above-named companies, as a rule, have not been tested by this Station. The list is as complete as we are able to give from our present knowledge and is given for the convenience of those intending to purchase cow-pea machinery. Before purchases are made, we would recommend an investigation of the machines manufactured by the different companies.

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No. 13....Experiments with Oats.
No. 15....Additional Experiments and Observations on Oat Smut.
No. 16....Experiments with Sorghum and with Sugar Beets.
No. 43....Experiments with Sorghum and Sugar Beets.
No. 52....Kansas Weeds—Preliminary Circular on Distribution.
No. 120....Tests of Forest Trees.
No. 121....Treatment and Utilization of Flood-damaged Lands.
No. 122....Blackleg and Vaccination.
No. 129....Kansas Mammals in their Relation to Agriculture.
No. 135....Grading Cream.
No. 136....Press Bulletins Nos. 125-151.
No. 137....Variations in the Test of Separator Cream.
No. 138....Effect of Bacteria in Wash-water of Butter.
No. 139....The Study of Corn.
No. 140....Milking Machines.
No. 141....Commercial Seeds of Brome-grass and of English and Kentucky Blue-grasses: Adulterants and Substitutes and their Detection.
No. 142....The Value of Oil in Road Improvement.
No. 143....Disposal of Dairy and Farm Sewage, and Water Supply.
No. 144....Small-grain Crops.
No. 145....Spraying.
No. 148....Law Regluating the Sale of Commercial Fertilizers.
No. 149....Prevention of Sorghum and Kafir-corn Smut.
No. 150....The Hen's Place on the Farm.
No. 151....Alfalfa Breeding.
No. 152....The Pocket Gopher.
No. 153....Deterioration of Red Texas Oats in Kansas.
No. 154....The Mound-building Prairie Ant.
No. 155....Alfalfa.
No. 156....The Yellow Berry Problem in Kansas Hard Winter Wheats.
No. 157....Studies on Hog Cholera and Preventive Treatment.
No. 158....Analyses of Registered Feeding-stuffs.
No. 159....Analyses of Eggs.

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Kansas State Agricultural College.

EXPERIMENT STATION.—Bulletin 161.

ED. H. WEBSTER, *Director.*

TECHNICAL BULLETIN.

Bacteriology Department.

WALTER E. KING, *Bacteriologist in Charge.*

THE INFLUENCE OF DEPTH OF CULTIVATION UPON SOIL BACTERIA AND THEIR ACTIVITIES.

BY

WALTER E. KING, *Bacteriologist.*
CHARLES J. T. DORYLAND, *Assistant in Soils.*

MANHATTAN, KANSAS,
AUGUST 12, 1909.
8—391

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Superintendent.

The Influence of Depth of Cultivation upon Soil Bacteria and Their Activities.

By

Walter E. King, *Bacteriologist.*
Charles J. T. Doryland, Assistant in Soils.

INTRODUCTION.

THERE are those who believe that future work in soil bacteriology will have considerable bearing upon the problem of maintaining soil fertility. This belief is founded upon the existing knowledge of soil bacteria, and the suggested part that bacterial action plays in preparing the soil for plant growth.

Granting that our present rather limited knowledge portends to show that soil bacteria and their activities are useful and essential attributes of fertile soil, it seems justifiable that attempts should be made to determine the influence of different conditions upon the number and specific activities of the bacteria living in various types of soil.

The consideration of the influence of depth of cultivation upon the soil bacteria and their activities is a broad subject, which embraces a host of minor problems. The whole problem can be determined only by an immense amount of experimental work and years of patient labor. The experiments outlined in the following pages, therefore, must be considered as preliminary and the suggested results as only forerunners of definite conclusions.

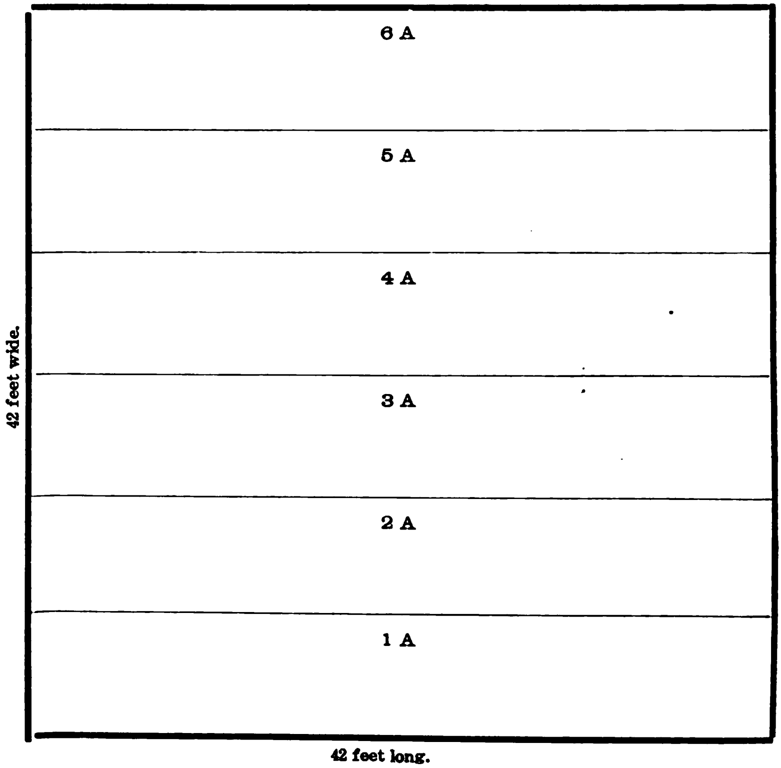
Part I.

PRELIMINARY EXPERIMENTS.

This work was designed and carried out as a preliminary experiment for the basis of further research in soil bacteriology under field conditions. The work was begun on March 7, 1908, and was continued fifteen weeks. At the end of this time the plan was broadened out, including more details of soil conditions. The first three weeks of the experiment were used in determining the number of bacteria in the soil under the existing conditions, so that the comparative results by different treatments must be drawn from the last twelve weeks' work.

The study included two types of soil as nearly opposite in character as it was possible to secure. Silt loam and fine sandy loam were selected. The silt loam is situated upon the upland Kansas State Agricultural College farm. This had previously been used for an experimental plot; the year previous it was planted to corn but received no special treatment or dressing. The sandy loam is located on the Kaw river bottom close to the stream; it had previously been used for general farming. The fall before this experiment was commenced it had received a liberal dressing of straw manure. A plot 42 x 42 feet was laid out on each field. The one on silt loam was called B; the one on sandy loam was called A. These plots were subdivided into six smaller plots, and called 1B, 2B, 3B, etc. Those of A were likewise named. The following diagram illustrates the plan of each plot:

Plot A.



Subplots 1A and 1B remained in the original condition and received no treatment, except to keep the weeds down. This was done by shaving them off at the surface of the ground with a hoe. The remainder of the subplots, from 2 to 6 of both A and B, were stirred to a depth of two inches after every rain, as soon as the soil was dry enough to till. Subplots 2, 3, 4, 5 and 6, of both A and B, were plowed to a depth of two, four, six, eight and ten inches, respectively.

In order to determine the influence of the different depths of cultivation on the number of bacteria, six samples were taken from each subplot every seventh day. These samples were taken every second inch to the depth of twelve inches. The estimates are given as so many million bacteria per cubic centimeter. The high bacterial content obtained in some instances is perhaps due to the methods used in this work. The volumetric method of collection and preparation of samples was used exclusively.

At the same time that samples were taken for bacterial determination, samples were also taken to determine the per cent. of moisture in the surface foot of the soil. Each plot was provided with a thermometer, so that the temperature could be recorded each time the samples were taken. The results are given in the following tables (I to XII):

TABLE I—PLOT A. Check plot, undisturbed.—Fine sandy loam (U. S. Soil Survey). Number of bacteria given as millions per cubic centimeter.

DATE.	Plot No.	Temp., C.	Per cent. water.	Number of bacteria at different depths.					
				2 in.	4 in.	6 in.	8 in.	10 in.	12 in.
Mar. 19①..	1A	10.0	20.17	9.70	10.92	8.64	8.82	4.74	2.88
" 25....	1A	10.0	20.10	11.16	14.26	13.68	8.00	5.40	2.52
Apr. 2....	1A	10.5	20.10	12.00	15.00	6.60	6.60	6.00	2.40
" 9....	1A	11.0	20.25	15.00	10.80	8.40	6.00	4.20	3.00
" 16....	1A	14.9	20.30	11.40	10.92	16.80	10.80	18.00	5.46
" 23....	1A	17.0	24.50	30.06	12.06	4.44	3.60	1.20	1.20
" 30....	1A	16.6	24.50	16.20	18.00	4.20	3.20	1.20	1.20
May 6....	1A	17.5	24.70	15.00	8.40	8.40	4.20	4.80	4.20
" 13....	1A	19.7	25.00	x	x	x	x	x	x
" 20....	1A	16.6	25.40	4.79	5.38	3.58	4.18	2.38	.59
" 27②..	1A	18.6	27.20	13.72	lost	5.32	2.40	5.32	1.10
Jun. 2....	1A	20.0	27.90	22.00	18.40	6.40	4.60	7.40	3.80
" 9....	1A	20.5	25.20	12.60	7.20	6.00	4.20	1.80	.60
Totals..........................				173.63	131.34	92.46	66.60	62.44	28.95
Averages..................				14.47	11.94	7.71	5.55	5.20	2.41

1. Determinations made on March 19 indicate number of bacteria at beginning of experiment.
2. Samples taken after field had been saturated for several days.

Moisture estimates indicate per cent. average in first foot, one determination being made for all plots.

In all cases "x" indicates a spreading growth on plate cultures which prevented counting of colonies.

TABLE II—PLOT 2A. Stirred to the depth of two inches.

DATE.	Plot No.	Temp.	Per cent. water.	Number of bacteria at different depths.					
				2 in.	4 in.	6 in.	8 in.	10 in.	12 in.
Mar. 25....	2A	10.0	20.17	13.32	20.88	10.08	10.00	1.98	6.84
Apr. 2....	2A	10.5	20.10	14.40	18.00	18.00	12.60	2.40	2.40
“ 9....	2A	11.0	20.25	11.40	12.00	9.36	8.70	7.20	4.80
“ 16....	2A	14.9	22.80	10.80	8.46	4.26	4.80	1.20	1.80
“ 23....	2A	17.0	24.60	11.40	9.00	29.52	13.20	18.60	4.26
“ 30....	2A	16.6	24.50	4.20	6.60	12.00	7.80	5.40	2.40
May 6....	2A	17.5	24.70	16.40	12.40	9.20	9.20	6.80	7.60
“ 13....	2A	19.7	25.00	x	x	x	x	x	x
“ 20....	2A	16.6	25.40	2.98	2.98	3.58	1.18	1.18	.68
“ 27....	2A	18.6	27.20	15.12	13.50	7.72	2.92	1.72	2.32
Jun. 2....	2A	20.0	27.90	11.80	17.20	10.00	1.00	1.60	2.20
“ 9....	2A	20.5	25.20	7.20	6.80	5.60	2.80	3.20	1.20
Totals....................				119.02	127.82	119.26	74.20	51 28	36.50
Averages..................				10.82	11.62	10.84	6.74	4.66	3.31

TABLE III—PLOT 3A. Stirred to depth of four inches.

DATE.	Plot No.	Temp.	Per cent. water.	Number of bacteria at different depths.					
				2 in.	4 in.	6 in.	8 in.	10 in.	12 in.
Mar. 25....	3A	(See plot 2A)....		34.20	42.80	19.80	17.28	8.28	4.68
Apr. 2....	3A	“	“	9.00	16.20	16.20	14.40	6.60	3.00
“ 9....	3A	“	“	15.00	28.20	①61.00	10.80	6.00	5.40
“ 16....	3A	“	“	4.80	4.26	9.00	3.66	1.92	1.92
“ 23....	3A	“	“	20.40	22.32	11.46	9.00	1.62	5.52
“ 30....	3A	“	“	9.00	2.60	8.40	2.40	2.40	.60
May 6....	3A	“	“	34.80	35.20	11.20	2.52	2.80	6.40
“ 13....	3A	“	“	x	x	x	x	x	x
“ 20....	3A	“	“	6.58	5.98	6.00	8.98	4.78	0.58
“ 27....	3A	“	“	16.72	13.72	10.10	10.12	4.10	1.10
Jun. 2....	3A	“	“	14.20	22.60	9.40	5.80	4.00	3.80
“ 9....	3A	“	“	4.80	4.80	6.00	4.00	1.20	.40
Totals....................				169.50	198.68	168.56	88.96	43.70	33.40
Averages..................				15.40	18.06	15.32	8.08	3.97	3.03

1. Bunch of manure is responsible for large number of bacteria.

TABLE IV—PLOT 4A. Stirred to depth of six inches.

DATE.	Plot No.	Temp.	Per cent. water.	Number of bacteria at different depths.					
				2 in.	4 in.	6 in.	8 in.	10 in.	12 in.
Mar. 25....	4A	(See plot 2A.)		11.04	11.28	8.16	8.16	5.28	4.00
Apr. 2....	4A	“	“	12.00	18.60	27.40	6.60	4.20	3.40
“ 9....	4A	“	“	9.00	12.60	14.40	16.80	9.60	5.40
“ 16....	4A	“	“	8.40	19.32	7.32	6.60	3.72	1.92
“ 23....	4A	“	“	10.32	42.60	39.66	16.32	7.80	3.00
“ 30....	4A	“	“	3.00	6.00	6.00	2.40	1.80	.60
May 6....	4A	“	“	14.80	15.60	13.60	2.20	1.60	2.80
“ 13....	4A	“	“	x	x	x	x	x	x
“ 20....	4A	“	“	5.98	7.78	①20.98	2.38	3.58	.98
“ 27....	4A	“	“	16.72	15.52	10.10	6.50	2.32	5.32
Jun. 2....	4A	“	“	11.60	15.60	8.00	5.20	.60	2.80
“ 9....	4A	“	“	3.60	7.60	6.40	4.80	.80	.05
Totals....................				106.46	172.50	162.02	77.96	41.30	30.27
Averages				9.67	15.68	14.73	7.08	3.75	2.75

1. Bunch of manure is responsible for large number of bacteria.

TABLE V—PLOT 5A. Stirred to a depth of eight inches.

DATE.	Plot No.	Temp.	Per cent. water.	Number of bacteria at certain depths.					
				2 in.	4 in.	6 in.	8 in.	10 in.	12 in.
Mar. 25....	5A	(See plot 2A)....		7.92	9.12	6.72	6.48	4.56	3.84
Apr. 2....	5A	"	"	12.40	26.40	①42.00	12.00	7.00	6.60
" 9....	5A	"	"	8.40	8.46	8.40	12.00	6.00	6.00
" 16....	5A	"	"	3.72	12.06	9.72	10.82	3.00	3.60
" 23....	5A	"	"	30.00	16.32	12.84	8.58	7.26	9.06
" 30....	5A	"	"	4.20	2.40	6.00	12.60	6.12	.62
May 6....	5A	"	"	8.88	14.00	15.60	30.80	6.80	6.00
" 13....	5A	"	"	x	x	11.98	x	x	x
" 20....	5A	"	"	19.18	8.40	x	13.78	2.98	3.58
" 27....	5A	"	"	6.00	9.00	17.32	7.70	lost	7.70
Jun. 2...	5A	"	"	11.20	4.60	11.80	19.20	2.00	12.00
" 9....	5A	"	"	9.60	6.80	12.60	5.60	.40	1.20
Totals....				121.50	117.56	154.98	139.06	46.12	60.20
Averages....				11.04	10.68	14.09	12.64	4.61	5.47

1. The large number of bacteria is due to manure.

TABLE VI—PLOT 6A. Stirred to a depth of ten inches.

DATE.	Plot No.	Temp.	Per cent. water.	Number of bacteria at different depths.					
				2 in.	4 in.	6 in.	8 in.	10 in.	12 in.
Mar. 25....	6A	(See plot 2A)....		9.12	10.80	7.92	8.16	13.20	1.44
Apr. 2....	6A	"	"	6.00	7.20	14.40	5.40	4.00	3.60
" 9....	6A	"	"	7.20	10.80	9.60	11.40	11.40	8.40
" 16....	6A	"	"	4.20	10.20	6.12	①........	16.20	5.52
" 23....	6A	"	"	6.72	10.20	10.80	18.75	10.92	7.20
" 30....	6A	"	"	6.00	9.00	3.60	3.00	5.40	6.60
May 6....	6A	"	"	①........	6.80	11.20	15.60	5.20	4.80
" 13....	6A	"	"	x	x	x	x	x	x
" 20....	6A	"	"	9.58	10.78	16.18	7.78	12.58	5.98
" 27....	6A	"	"	12.50	lost	16.10	lost	lost	8.32
Jun. 2....	6A	"	"	4.00	5.60	4.40	8.80	4.60	1.60
" 9....	6A	"	" ...	8.00	8.80	11.20	4.40	2.40	5.60
Totals....				73.82	90.18	111.52	83.29	85.90	59.06
Averages....				7.33	9.01	10.13	9.27	8.59	5.37

1. So many colonies that they could not be counted.

TABLE VII—PLOT B. Check plot, undisturbed.—Preliminary experiment—Marshall silt loam (U. S. Soil Survey). Numbers indicate millions of bacteria per cubic centimeter.

DATE.	Plot No.	Temp.	Per cent. water.	Number of bacteria at different depths.					
				2 in.	4 in.	6 in.	8 in.	10 in.	12 in.
Mar. 19....	1B	10.0	21.87	7.26	8.96	11.66	4.21	2.97	2.65
" 25....	1B	9.2	21.87	9.08	13.04	9.36	5.04	2.52	1.62
Apr. 2....	1B	10.0	22.60	4.30	4.90	7.30	1.80	4.20	1.20
" 9....	1B	13.0	22.25	9.00	18.60	2.00	2.40	1.20	2.40
" 16....	1B	15.0	23.80	7.20	12.00	16.20	8.40	2.40	.96
" 23....	1B	14.9	24.60	10.20	4.92	5.40	1.20	3.06	1.30
" 30....	1B	14.0	25.50	12.24	15.84	4.92	3.60	3.60	1.80
May 6....	1B	12.4	25.70	9.61	9.60	8.52	9.12	6.60	2.40
" 13....	1B	15.6	25.90	x	x	x	x	x	x
" 20....	1B	19.4	25.40	7.80	8.41	4.20	x	.30	.09
" 27....	1B	19.0	28.20	10.00	7.60	1.60	1.10	.30	.16
Jun. 2....	1B	18.0	28.90	6.40	8.80	1.00	.60	.30	.50
" 9....	1B	20.0	26.80	25.20	11.40	9.60	10.20	3.60	2.40
Totals....				118.29	124.07	81.76	47.67	31.05	17.48
Averages....				9.85	10.34	6.81	4.33	2.58	1.45

TABLE VIII—PLOT 2B. Stirred to depth of two inches.

DATE.	Plot No.	Temp.	Per cent. water.	Number of bacteria at different depths.					
				2 in.	4 in.	6 in.	8 in.	10 in.	12 in.
Mar. 25....	2B	9.2	21.87	9.02	6.72	4.82	2.88	2.88	3.24
Apr. 2....	2B	10.0	22.60	6.10	5.40	3.60	2.40	1.80	1.20
" 9....	2B	13.0	22.25	18.60	7.20	7.20	4.80	2.40	.60
" 16....	2B	15.0	23.80	10.80	10.20	15.00	12.00	12.00	7.20
" 23....	2B	14.9	24.60	8.64	7.80	1.20	3.06	.60	.50
" 30....	2B	14.0	25.50	6.90	52.20	6.20	3.18	.66	1.86
May 6....	2B	12.4	25.70	12.60	9.00	10.20	5.40	9.18	6.12
" 13....	2B	15.6	25.90	x	x	x	x	x	x
" 20....	2B	19.4	25.40	8.40	2.41	1.20	.66	.12	.05
" 27....	2B	19.0	28.20	4.00	4.70	.70	.70	1.20	.40
Jun. 2....	2B	18.0	28.90	13.60	14.80	1.00	1.00	.50	.80
" 9....	2B	20.0	26.80	15.60	11.40	6.60	4.20	3.60	1.80
Totals..........				114.26	131.88	57.22	40.28	34.94	23.77
Averages..........				10.38	11.99	5.20	3.66	3.17	2.16

TABLE IX—PLOT 3B. Stirred to depth of four inches.

DATE.	Plot No.	Temp.	Per cent. water.	Number of bacteria in different depths.					
				2 in.	4 in.	6 in.	8 in.	10 in.	12 in.
Mar. 25....	3B	9.2	21.89	8.64	6.96	2.53	2.18	1.88	3.24
Apr. 2....	3B	10.0	22.60	8.50	12.60	8.40	1.80	1.80	6.60
" 9....	3B	13.0	22.25	7.20	12.60	5.40	4.60	4.60	2.90
" 16....	3B	15.0	23.80	9.72	10.32	21.12	20.40	20.40	9.60
" 23....	3B	14.9	24.60	10.20	6.00	1.80	1.80	1.80	1.86
" 30....	3B	14.0	25.50	10.20	12.78	13.26	3.12	3.12	1.20
May 6....	3B	12.4	25.70	9.18	9.72	6.00	6.60	6.60	9.00
" 13....	3B	15.6	25.90	x	x	x	x	x	x
" 20....	3B	19.4	25.40	4.80	6.60	1.80	.27	.27	.21
" 27....	3B	19.0	28.20	10.70	8.90	10.70	1.20	1.20	.10
Jun. 2....	3B	18.0	28.90	24.40	11.60	2.20	.20	.20	.10
" 9....	3B	20.0	26.80	17.40	16.80	2.40	9.00	9.00	6.60
Totals..........				121.94	114.88	75.61	51.17	50.37	35.41
Averages..........				11.08	10.44	6.87	4.65	4.58	3.21

TABLE X—PLOT 4B. Stirred to a depth of six inches.

DATE.	Plot No.	Temp.	Per cent. water.	Number of bacteria in certain depths.					
				2 in.	4 in.	6 in.	8 in.	10 in.	12 in.
Mar. 25....	4B	9.2	21.87	4.36	4.32	12.96	6.04	3.60	3.60
Apr. 2....	4B	10.0	22.60	5.40	7.80	9.00	1.80	1.80	1.20
" 9....	4B	13.0	22.25	12.00	17.40	19.20	4.20	4.80	1.20
" 16....	4B	15.0	23.80	8.64	15.12	13.60	12.06	9.06	①16.26
" 23....	4B	14.9	24.60	6.12	3.60	4.32	.50	.48	1.14
" 30....	4B	14.0	25.50	9.00	5.10	4.82	5.43	3.00	.59
May 7....	4B	12.4	25.70	6.72	4.80	8.90	8.60	6.78	4.32
" 14....	4B	15.6	25.90	x	x	x	x	x	x
" 21....	4B	19.4	25.40	14.40	8.40	3.00	.44	.43	.39
" 28....	4B	19.0	28.20	10.20	6.60	3.50	3.60	.16	.36
Jun. 3....	4B	18.0	28.90	16.80	15.90	17.20	1.60	.40	.20
" 10....	4B	20.0	26.80	17.40	9.00	9.60	5.40	3.00	6.60
Totals..........				108.04	98.04	106.60	49.67	33.51	35.86
Averages..........				9.82	8.91	9.69	4.51	3.04	3.26

1. No adequate reason can be given for the exceptionally high number.

TABLE XI—PLOT 5B. Stirred to depth of 8 inches.

DATE.	Plot No.	Temp.	Per cent. water.	Number of bacteria in different depths.					
				2 in.	4 in.	6 in.	8 in.	10 in.	12 in.
Mar. 25....	5B	9.2	21.87	8.82	8.20	8.64	8.52	8.28	2.52
Apr. 2....	5B	10.0	22.60	6.00	7.20	7.40	3.00	2.40	1.20
" 9....	5B	13.0	22.25	18.00	19.80	9.00	4.20	3.60	.60
" 16....	5B	15.0	23.80	7.26	13.32	13.20	4.26	3.60	7.80
" 23....	5B	14.9	24.60	7.20	4.20	4.80	1.80	8.50	4.20
" 30....	5B	14.0	25.50	16.32	18.60	14.84	9.20	.80	1.20
May 6....	5B	12.4	25.70	10.32	9 00	11.40	10.30	7.20	6.60
" 14....	5B	15.6	25.90	x	x	x	x	x	x
" 21....	5B	19.4	25.40	x	x	6.00	9.60	.16	.23
" 28....	5B	19.0	28.20	14.30	8.30	7.70	2.30	1.70	1.10
Jun. 3....	5B	18.0	28.90	4.00	19.60	10.60	2.00	.10	.90
" 10....	5B	20.0	26.80	9.00	27.00	12.60	4.80	4.20	1.20
Totals..............................				101.22	136.22	106.18	59.98	40.54	27.55
Averages......................				10.12	13.52	9.65	5.45	3.68	2.50

TABLE XII—PLOT 6B. Stirred to a depth of ten inches.

DATE.	Plot No.	Temp.	Per cent. water.	Number of bacteria in different depths.					
				2 in.	4 in.	6 in.	8 in.	10 in.	12 in.
Mar. 25....	6B	9.2	21.87	2.88	3.60	19.64	2.88	2.52	1.42
Apr. 2....	6B	10.0	22.60	2.40	8.40	3.20	3.60	14.40	2.40
" 9....	6B	13.0	22.25	7.20	6.60	7.80	7.90	7.20	6.60
" 16....	6B	15.0	23.80	10.20	24.60	27.00	12.06	12.00	12.00
" 23....	6B	14.9	24.60	9.18	13.20	6.06	1.00	.30	.20
" 30....	6B	14.0	25.50	5.52	18.88	16.64	6.00	5.60	.80
May 7....	6B	12.4	25.70	3.18	10.80	12.00	7.80	8.40	6.60
" 14....	6B	15.6	25.90	x	x	x	x	x	x
" 21....	6B	19.4	25.40	3.00	3.00	4.20	3.00	4.80	3.60
" 28....	6B	19.0	28.20	6.50	9.00	9.50	3.50	1.10	1.70
Jun. 3....	6B	18.0	28.90	1.00	15.40	16.00	9.40	.80	.60
" 10....	6B	20.0	26.80	6.60	11.40	15.00	15.00	7.20	5.40
Totals..............................				57.66	124.88	137.04	72.14	64.32	41.32
Averages......................				5.24	11 35	12.45	6.56	5.85	3.75

The great variation in the results is at once apparent. This fluctuation, however, generally occurs in quantitative soil bacteriological work. Samples taken 100 feet apart may often show a variation of 20 to 40 per cent., while those taken from the same depth, only a few feet apart, may vary from 10 to 20 per cent. Commencing at the surface, bacteria increase in number up to the fifth or sixth inch, depending upon the depth of plowing, then rapidly decrease, and disappear at a depth of about seven feet below the surface foot.

Some of the exceptional irregularities in the table can be explained. For instance, on April 23, plot 2A showed twenty-nine million bacteria per cubic centimeter at six inches, thirteen million at eight inches, and eighteen million at ten inches in depth. These high numbers are due to a portion of manure which had been plowed under the year previous and had not entirely decayed. The piece of manure, to all appearances, had been pressed into some rodent's runway by the horses' hoofs. The average depth of the previous plowing was approximately four inches. The same thing occurred in the samples taken on the same day on plot 4A. The number of bacteria reached forty-two million per cubic centimeter in the fourth inch and thirty-nine million per cubic centimeter in the sixth inch. Again, on April 9, plot 3A showed sixty-one million per cubic centimeter in the sixth. This was also due to manure. Another factor which probably induced these large numbers was the increased temperature, followed by a warm two-inch rain which fell about twenty-four hours before the samples were taken. This view is strengthened by glancing through the twelve tables and comparing estimates for April 23. The sandy soils, which allowed a rapid percolation of water, showed a marked increase in number of bacteria, even in the tenth and twelfth inches, but the more tenacious silt soils showed a decrease in the number of bacteria. The temperature of the silt during the preceding week was 15 degrees C., while on April 23 it had fallen to 14.9 degrees C. The temperature of the sand was 14.9 degrees on April 16, while on April 23 it had risen to 17 degrees C. Plot 4B shows an unaccountable high number in the twelfth inch on the 16th of April.

The tables show that the number of bacteria increased and diminished with more or less regularity. It was also observed on the plate cultures that one species of bacteria would predominate, and at times almost entirely exclude other species. For instance, on April 9 the sixty-one million count consisted almost entirely of minute oval colonies, all of which were apparently of one species.

On May 13 both plots A and B gave results that were exceptional. On the plate cultures there were innumerable tiny colonies so closely set that they could not be accurately estimated. However, estimates placed them at one hundred million per cubic centimeter. One week later, May 20, all the plots showed a marked decrease in the number of organisms. This was perhaps due to the excessive moisture, the ground having been completely saturated for several days; nevertheless, the growth on the agar plates was apparently all of one species.

The influence of moisture is perhaps best shown by the results obtained between May 20 and June 2. During this time the soil was more or less saturated. It will be noticed that the number of bacteria diminished quite markedly during this period, and rose again on June 2 nearly to its former height, followed by a decrease on June 9. This was after the per cent. of moisture in the sandy soil had fallen from 27.9 to 25.2 per cent., and from 28.9 to 26.8 in the silt.

A better idea of the influence of deep plowing can be obtained by arranging the averages of tables from 1 to 6 in one table and the averages from tables 7 to 12 in another and comparing the results:

TABLE XIII. Sandy loam.

Depth of sample.	Average number bacteria.					
	1A. Undisturbed.	2A. Stirred 2 in.	3A. Stirred 4 in.	4A. Stirred 6 in.	5A. Stirred 8 in.	6A. Stirred 10 in.
2 inches	14.47	10.82	15.40	9.67	11.04	7.33
4 "	11.94	11.62	18.06	15.68	10.68	9.01
6 "	7.71	10.84	15.32	14.73	14.09	10.18
8 "	5.55	6.74	8.08	7.08	12.64	9.27
10 "	5.20	4.66	3.97	3.75	4.19	8.59
12 "	2.41	3.81	3.08	2.75	5.47	5.37
Sum of averages	47.28	47.99	63.86	53.66	58.11	49.70

TABLE XIV. Silt loam.

Depth of sample.	Average number bacteria.					
	1B. Undisturbed.	2B. Stirred 2 in.	3B. Stirred 4 in.	4B. Stirred 6 in.	5B. Stirred 8 in.	6B. Stirred 10 in.
2 inches	9.85	10.38	11.08	9.82	10.12	5.24
4 "	10.34	11.99	10.44	8.91	13.52	11.35
6 "	6.81	5.20	6.87	9.69	9.65	12.45
8 "	4.33	3.66	4.65	4.51	5.45	6.56
10 "	2.58	3.17	4.58	3.04	3.68	5.85
12 "	1.45	2.16	3.21	3.26	2.50	3.75
Sum of averages	35.36	36.56	40.83	39.23	44.92	45.20

The average in tables XIII and XIV does not give the total number of bacteria in a surface foot of soil, but shows the ratio of the number of bacteria. For instance, in table XIII (sandy soil) the sum of the averages for the unstirred check plot was 47.28 million. The bacterial contents of 3A, 4A and

5A, stirred four, six and eight inches deep, were 63.86, 53.66 and 58.11 million, respectively. In the plot which was stirred ten inches deep the number was slightly less than in the plot which was stirred four inches deep. The plots which were plowed to a depth of two, four, six, eight and ten inches showed an increase in the number of bacteria of 0.71, 16.58, 6.38, 10.83 and 2.42 millions per cubic centimeter, respectively.

Upon examination of table XIV it will be found that in the silt soil the increase in the number of bacteria, due to deeper plowing, is not so rapid as in the sandy soil, but much more uniform. Commencing with plot 2B, the number of bacteria shows a gradual increase from 1.20 million in the two-inch plowing to 9.84 million in the ten-inch plowing.

The percentage of increase of bacterial content is shown in table XV.

TABLE XV.

Subplot number.	Sum of the averages.	Depth of cultivation.	Percentage of increase.
1A sand	47.28	Check, undisturbed	100.00
1B silt	35.86	" "	100.00
2A sand	47.99	Plowed two inches deep	101.50
2B silt	36.56	" " " "	103.89
3A sand	63.86	" four " "	135.06
3B silt	40.83	" " " "	115.46
4A sand	53.66	" six " "	113.58
4B silt	39.23	" " " "	110.94
5A sand	58.11	" eight " "	122.90
5B silt	44.92	" " " "	124.20
6A sand	49.70	" ten " "	105.11
6B silt	45.20	" " " "	126.89

From the results in table XV it appears that extra deep cultivation tends to greater increase in numbers of bacteria upon the tenacious silt soil than upon the more porous sandy soils. This effect in favor of the silt soil is perhaps due largely to the increased aeration. At the same time it is well to observe that the silt soil had previously been plowed about six inches deep, while the sandy soil had been plowed on an average of four inches deep. Hence, in stirring the silt soil ten inches deep, four inches of new soil were exposed, while with the sandy soils that were stirred the same depth six inches of new soil were brought into action. This deep plowing would tend to place the surface soil, high in humus content, at a depth that is less favorable for highest bacterial development and at the same time place the previously unstirred soil, of low humus content, in the most favorable growing area.

If, however, the field were stirred to a depth of ten inches for several years, so as to incorporate humus into the surface ten inches of soil, it is reasonable to suppose that extra deep plowing might be more favorable for the development of bacteria in the sandy soil than it appears to be from the above table. At the same time, however, several years of deep plowing would also be more beneficial to bacterial development in the heavier soils.

These preliminary experiments show that when plowed land is compared with unplowed land it is found that:

Silt—	
Plowed 4 inches deep increases the number of bacteria......	15.46%
Plowed 6 inches deep increases the number of bacteria......	10.94
Plowed 8 inches deep increases the number of bacteria......	24.20
Plowed 10 inches deep increases the number of bacteria......	26.89
Sand—	
Plowed 4 inches deep increases the number of bacteria......	35.06%
Plowed 6 inches deep increases the number of bacteria......	13.53
Plowed 8 inches deep increases the number of bacteria......	22.90
Plowed 10 inches deep increases the number of bacteria......	5.11

Part II.

CONTINUATION OF THE EXPERIMENTS.

On June 20, 1908, the experiments were continued, and determinations were made according to the following plan:

PLOT A (42 x 42 feet).

SUBPLOT A1. Six samples to be taken every 14 days, volumetric method. (Undisturbed.) (See note.)	SUBPLOT A1. Six samples to be taken every 14 days, volumetric method. (Unstirred.)
A2. Six samples to be taken every 14 days, volumetric method. (Stirred 2 inches.)	A2. Six samples to be taken every 14 days, volumetric method. (Stirred 2 inches on March 18 and June 20.)
A3. Six samples to be taken every 14 days, volumetric method. (Stirred 4 inches on March 18.)	A3. Six samples to be taken every 14 days, volumetric method. (Stirred 4 inches on March 18 and June 20.)
A4. Six samples to be taken every 14 days, volumetric method. (Stirred 6 inches on March 18.)	A4. Six samples to be taken every 14 days, volumetric method. (Stirred 6 inches on March 18 and June 20.)
A5. Six samples to be taken every 14 days, volumetric method. (Stirred 8 inches on March 18.)	A5. Six samples to be taken every 14 days, volumetric method. (Stirred 8 inches on March 18 and June 20.)
A6. Six samples to be taken every 14 days, volumetric method. (Stirred 10 inches on March 18.)	A6. Six samples to be taken every 14 days, volumetric method. (Stirred 10 inches on March 18 and June 20.)

NOTE.—Eighteen samples taken by gravimetric method and eighteen samples by volumetric method at the same time and place.

One-half of each subplot in A and also one-half of each subplot in B* were replowed to the same depth as on March 18, in order to see if further stirring of the soil would increase the number and activities of the soil organisms.

The purpose of taking gravimetric samples was to obtain results which would afford a basis for a comparison of the two methods of soil sampling. The gravimetric or weighed samples were secured from the same plots and at the same depth and place as the volumetric or measured samples. There were two sets of gravimetric samples taken, in order to determine whether drying materially decreased the number of bacteria per gram. One set of gravimetric samples with duplicates was taken immediately to the right of the volumetric samples; the other set with duplicates was taken immediately to the left of the volumetric samples, so as to obtain under the same conditions, as nearly as possible, the same type of soil.

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* Plot B, 42 x 42 feet, duplicate of Plot A.

The method employed for taking and caring for individual samples will be discussed under "Quantitative Bacteriological Analysis." After taking the samples to the laboratory, one gravimetric set with duplicates was immediately subjected to culture tests; the other set with duplicates was placed between sheets of sterile filter-paper until air dry. Twenty-four hours was found sufficient for that purpose. They were then treated as were the other samples.

BACTERIAL ACTIVITIES AND INFLUENCING CONDITIONS.

In order to find the influence of aeration upon the biochemic characters of bacteria, determinations were made of the production of ammonia, reduction of nitrates to nitrites, and the production of gas in one-per-cent. solutions of glucose, lactose and saccharose bouillon.

Ammonia Production.—The relative amounts of ammonia in the different samples of soil were determined in the following way: One cubic centimeter of soil was completely suspended in nineteen cubic centimeters of sterile, ammonia-free, distilled water. Two cubic centimeters of this soil suspension were transferred to fifty cubic centimeters of nutrient agar, having a reaction of 1.5 acid to phenolpthalein. The agar was distributed in Erlenmeyer flasks of 250 cc. capacity. The flasks were then closed and allowed to stand for five days. At the end of that time ten cubic centimeters of sterile, nitrogen-free water were introduced and allowed to stand for ten minutes. It was then drawn off and tested for ammonia with Nessler's solution. The color reaction was compared with standard solutions and the results recorded as so many parts of ammonia per million. These standard solutions were prepared by placing fractional percentages of ammonium chloride in nitrogen-free water.

Gas Production.—The production of gas was determined in the usual way by using the common sugar bouillon media in fermentation tubes, each of which were inoculated with two cubic centimeters of soil suspension.

Reduction of Nitrates to Nitrites.—The denitrifying properties, or reduction of nitrates to nitrites, were determined by inoculating with 2 cubic centimeters of soil suspension, 10 cubic centimeters of Witte's peptone medium, which contained 0.2 gram of potassium nitrate per 1000 cubic centimeters. The tubes were allowed to stand for five days and then tested for nitrites by the addition of sulfanilic acid and naphthylamine chlorid. The results were compared with a standard and recorded as so many parts of nitrites per million.

Temperature.—In the preliminary work the temperature was recorded for the surface foot, but commencing with July 6, the temperature was recorded for each successive second inch up to one foot, or for each soil sample taken.

Acidity of Soil.—At the beginning of the experiment the soil showed acid to litmus at the end of thirty minutes, while at the end of the experiment it showed acid to litmus at the end of ten minutes.

Field Notes.—The condition of the soil surface, the time which had elapsed since the last rain, the amount of precipitation, and other factors such as masses of undecomposed organic matter, plowed soil, unstirred subsoil and burrows or heavy roots were recorded when samples were taken.

Mechanical Analyses.—A mechanical analysis was made of each of the two plots of soil under observation. The results of these analyses were as follows:

SILT SOIL, PLOT B.

Humus	3.15	per cent.
Volatiles	4.86	"
Fine gravel	.00	"
Coarse sand	.20	"
Medium sand	.26	"
Fine sand	.46	"
Very fine sand	24.16	"
Silt	38.91	"
Clay	28.00	"
Total	100.00	per cent.

SANDY SOIL, PLOT A.

Humus	3.25	per cent.
Volatiles	5.86	"
Fine gravel	.00	"
Coarse sand	.28	"
Medium sand	.38	"
Fine sand	3.72	"
Very fine sand	64.80	"
Silt	17.18	"
Clay	4.53	"
Total	100.00	per cent.

Number and Manner of Taking Samples.—From each half of the subplots which were plowed on March 18, and from each half of the subplots which were plowed on March 18 then replowed on June 20, six samples for bacterial determination were taken every fourteenth day. Six samples with duplicates for volumetric bacterial determination were taken from check plot A1 and the same number from check plot B1.

QUANTITATIVE BACTERIOLOGICAL ANALYSIS.

One of the difficult problems in soil bacteriological technique is that relating to the proper method of taking and measuring samples for quantitative determination. It is the general custom of bacteriologists to compare the number of bacteria per gram of dry soil. This is sometimes called the gravimetric or gram method.

In the present experimental work the volumetric method has been used. One cubic centimeter of soil was placed in a sterile test-tube to which was added 19 cc. of sterile distilled water. This was shaken for five minutes, and from each tube, by means of a sterile platinum loop, which was constructed and graduated to hold one cubic millimeter of water, approximately one cubic millimeter of the soil suspension was transferred into 10 cc. of sterile liquefied agar. The inoculated medium was then poured into a sterile Petri dish. This method is undoubtedly inaccurate, as it is difficult to measure such substances as soil in terms of cubic centimeters. However, for the purpose of securing comparative results, as in the present work, either method may be used. In other words, the comparative number of bacteria in soil which has been plowed two, four, six, eight, ten and twelve inches deep may be found by either the volumetric or gravimetric method and expressed as so many bacteria per cubic centimeter or per gram. The final results would appear to be correct so long as one or the other method of collecting samples is followed with uniformity throughout the work.

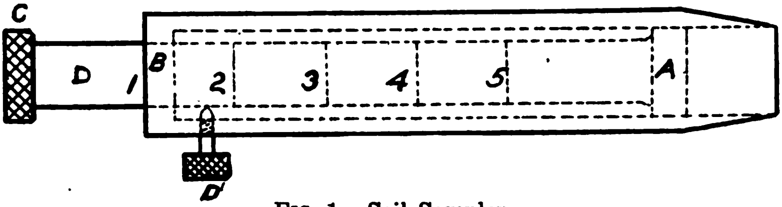

FIG. 1. Soil Sampler.

OBTAINING SAMPLES, AND BACTERIOLOGICAL TECHNIQUE.

The field outfit used in the work consisted of a small steel soil sampler, a spade, a measure, a sample case and a gasoline blow-torch. The soil sampler (fig. 1) is made of steel and consists of a steel tube seven centimeters long with an inside diameter of three-eighths inch and an outside diameter of seven-sixteenths inch. The plunger (D), with a plunger-rod one-eighth inch in diameter, is connected with the cylinder through a one-eighth inch hole (B), and is clamped and held at the desired place by the set-screw (*D*). The plunger-head (A) is just a working fit inside the cylinder. The plunger-rod (D) is graduated so that the plunger-head allows 1, 2, 3 or 4 cc. of soil to be taken, as desired.

The Sample Case.—The sample case (figs. 2 and 3) is 24 inches long, 18 inches high, and 12 inches wide. A lid, to which is attached the handle, covers the entire top. This is raised and the two catches at either end are released, which allows the case to open. On each side of the case, running the entire length, are three perforated shelves for holding test-tubes. The top shelf is two inches wide and holds 20 test-tubes. The second shelf is four inches wide and holds 20 test-tubes, while the lower shelf is six inches wide and holds the same number of tubes. The entire case holds 120 test-tubes, and when full weighs 7.45 kilograms.

The reason for having the shelves of different widths can be seen in the cut, as it allows the handling of one row of test-tubes without disturbing the others. The test-tube perforations are numbered to correspond with the depth of the sample and number of the plot, so that when a sample is taken the corresponding test-tube can be filled and replaced, thus

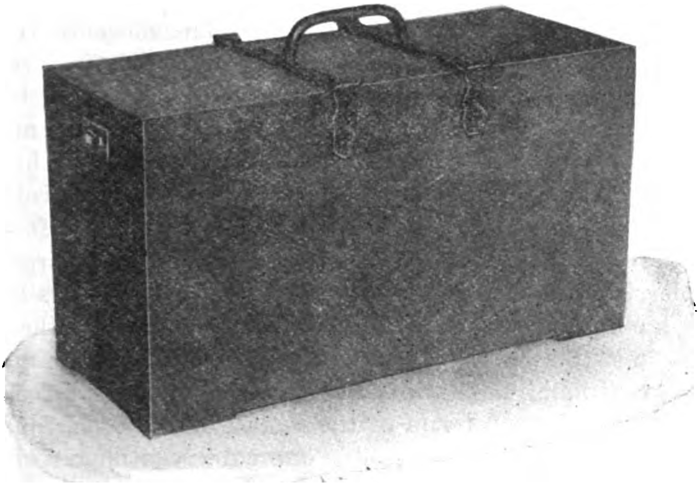

FIG. 2. Sample case, closed.

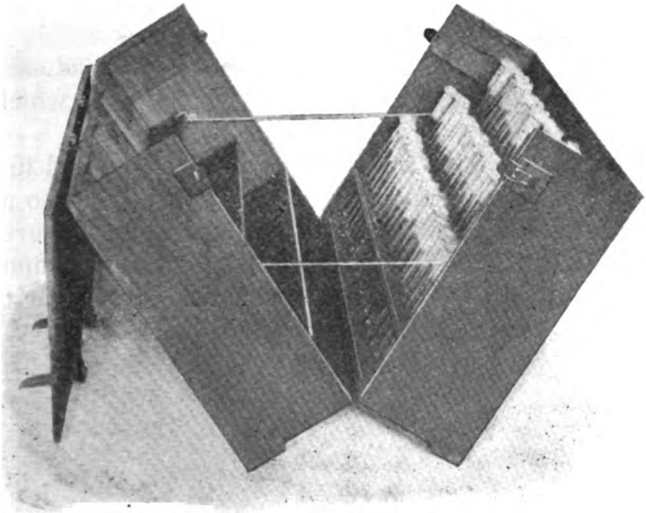

FIG. 3. Sample case, opened.

doing away with needless labeling of tubes. The case can be transferred to the laboratory and the cultures made.

The measure consists of a lath two feet long into which has been bored one-half inch holes every two inches, commencing with the second inch.

Taking the Samples.—To take the samples, dig a hole about a foot square, to the required depth. With a sterile spatula shave off foreign dirt from one bank. The measure is then placed against this bank and held so that a hole is just two inches below the surface. The sampler is then adjusted to take, say, 1 cc. (see fig. 1). After sterilizing the steel sampler in a blow-torch, with the right hand pass the point through the hole in the measure and force it into the soil, turning it once to free the outside from the soil. With the left hand take the corresponding test-tube from the case. Withdraw the sampler, holding it between the first and second fingers of the right hand, loosen the set-screw with the left, draw the plug (of the test-tube) with the back of the third and fourth fingers of the right hand, flame the mouth of the tube, then stroke the sample with the outer rim of the mouth of the tube, thus obtaining as accurately as possible one cubic centimeter of soil. Insert the sampler about one-half inch within the test-tube, then place the thumb of the right hand upon the plunger-head and force the sample into the test-tube. Withdraw the sampler, replace the plug, and place the tube in the rack.

The samples are then taken to the laboratory and each tube receives 19 cc. of sterilized distilled water, after which it is shaken until all the soil particles have separated.

A millimeter loop of this soil suspension is placed in 10 cc. of liquefied nutrient agar having a reaction of +1.5 to phenolpthalein, and the inoculated medium shaken and poured into a Petri dish. The plate cultures were kept at a temperature of about 23 degrees C. The colonies were counted at the expiration of from twenty to twenty-four hours.

TABLE I. Comparative number of bacteria per gram and per cubic centimeter. Plot A, wet.

Depth, inches.	7—6	No. of bacteria.		7—20	No. of bacteria.		8—8	No. of bacteria.		8—17	No. of bacteria.		8—31	No. of bacteria.	
	Wt. of sample.	Per cc.	Per gm.	Wt. of sample.	Per cc.	Per gm.	Wt. of sample.	Per cc.	Per gm.	Wt. of sample.	Per cc.	Per gm.	Wt. of sample.	Per cc.	Per gm.
2	1.248	10.20	8.17	1.25	11.20	8.96	1.25	17.60	14.00	1.30	8.40	6.58	1.21	3.60	2.97
2D*	1.25	15.00	12.00	1.16	9.60	8.27	1.25	8.00	6.40	1.29	25.20	19.45	1.22	2.60	2.14
4	1.236	22.80	18.40	1.19	16.80	14.11	1.23	7.20	5.84	1.18	8.40	7.11	1.18	6.60	5.98
4D	1.30	45.00	34.60	1.20	12.00	10.00	1.20	6.40	5.33	1.17	5.40	4.61	1.20	6.00	5.00
6	1.29	11.40	8.83	1.30	5.60	4.30	1.24	6.40	5.16	1.17	10.80	9.23	1.24	6.00	4.83
6D	1.40	23.00	11.64	1.28	4.80	3.70	1.19	9.60	8.06	1.20	7.20	6.00	1.24	6.60	5.32
8	1.31	8.40	6.41	1.10	4.80	4.30	1.30	7.20	5.53	1.19	3.60	3.02	1.26	6.00	4.75
8D	1.23	13.80	11.21	1.09	5.60	5.10	1.28	3.60	2.81	1.20	4.80	4.00	1.21	4.20	3.47
10	1.20	6.00	5.00	1.24	3.60	2.00	1.19	4.80	4.03	1.18	.20	.153	1.19	1.80	1.51
10D	1.19	5.40	4.53	1.30	2.40	1.84	1.24	2.00	1.61	1.24	6.60	5.32	1.20	lost	lost
12	1.30	6.00	4.65	1.23	3.20	2.60	1.30	2.40	1.80	1.20	1.00	.833	1.23	1.20	.97
12D	1.26	6.00	4.76	1.20	4.00	3.33	1.30	2.10	1.61	1.21	.34	2.80	1.22	lost	lost
Totals	....	173.00	180.20	....	83.60	68.51	....	77.30	62.18	....	81.94	66.586	....	44.60	36.89

* D indicates check or duplicate samples.

TABLE II. Number of bacteria per gram. Plot A, dry.

Depth, inches.	7—6	No. of bacteria.		7—20	No. of bacteria.		8—8	No. of bacteria.		8—17	No. of bacteria.		8—31	No. of bacteria.	
	Wt. of sample.	Per cc.	Per gm.	Wt. of sample.	Per cc.	Per gm.	Wt. of sample.	Per cc.	Per gm.	Wt. of sample.	Per cc.	Per gm.	Wt. of sample.	Per cc.	Per gm.
2	1.04	18.00	17.30	0.98	9.60	8.79	1.004	no	result	1.043	13.80	18.20	1.036	5.00	4.80
2D	1.065	34.80	32.60	1.015	5.60	5.40	1.121	20.40	18.20	1.07	10.20	9.53	1.05	2.40	2.08
4	1.112	15.60	18.10	1.05	7.20	6.80	1.085	8.80	8.10	1.06	8.40	7.92	1.06	6.00	5.67
4D	1.062	32.40	30.50	1.04	4.80	4.40	1.075	18.00	16.00	1.05	15.00	14.30	1.06	4.80	4.52
6	1.103	16.80	15.20	1.045	4.80	4.40	1.05	11.20	10.66	1.039	7.20	6.80	1.043	7.20	6.90
6D	1.05	15.00	14.28	1.07	8.00	7.47	1.08	26.40	24.44	1.071	9.60	8.90	1.021	7.20	7.00
8	1.14	7.20	6.30	1.02	3.20	3.08	1.028	9.60	8.60	1.04	3.60	3.46	1.06	3.80	3.58
8D	1.075	13.80	12.80	1.07	5.60	5.23	1.099	14.40	13.10	1.03	4.80	4.66	1.04	2.40	2.30
10	1.07	7.10	6.72	.99	.80	.76	1.031	7.20	6.09	1.067	1.80	1.70	1.04	1.40	1.34
10D	1.049	1.80	1.70	1.05	4.00	3.80	1.025	11.40	11.10	1.09	1.20	1.00	1.07	lost	lost
12	.965	8.40	8.70	1.055	.80	.76	1.04	3.60	3.46	1.05	1.20	1.14	1.09	1.40	1.29
12D	1.078	4.20	3.80	1.047	.80	.76	1.03	10.80	10.44	1.05	2.80	2.66	1.05	lost	lost
Totals	....	175.20	163.00	....	55.20	51.60	....	141.80	130.19	....	79.60	75.27	....	41.60	39.48

TABLE III. Number of bacteria per gram. Plot B, wet.

Depth, inches.	7—9	No. of bacteria.		7—23	No. of bacteria.		8—6	No. of bacteria.		8—20	No. of bacteria.		9—3	No. of bacteria.	
	Wt. of sample.	Per cc.	Per gm.	Wt. of sample.	Per cc.	Per gm.	Wt. of sample.	Per cc.	Per gm.	Wt. of sample.	Per cc.	Per gm.	Wt. of sample.	Per cc.	Per gm.
2	1.135	19.20	16.00	1.14	14.80	14.21	1.21	3.00	2.48	1.11	2.00	1.80	1.12	2.40	2.14
2D	1.129	19.20	16.90	1.142	12.60	11.00	1.20	10.20	8.50	1.11	12.80	11.50	1.16	7.80	6.61
4	1.20	7.20	6.00	1.136	2.40	2.11	1.24	2.40	1.90	1.12	4.80	4.28	1.20	5.40	4.50
4D	1.134	36.80	32.40	1.147	12.60	10.90	1.19	5.40	4.50	1.16	7.80	6.20	1.22	4.80	3.90
6	1.12	3.00	2.67	1.19	2.40	2.01	1.10	4.20	3.818	1.20	.52	.433	1.33	4.80	3.60
6D	1.021	9.60	9.40	1.20	2.40	2.14	1.00	1.80	1.80	1.09	7.20	6.60	1.01	10.80	10.60
8	1.032	.56	.542	1.21	4.20	3.47	1.14	1.20	1.05	1.10	.10	.909	1.19	4.80	4.03
8D	1.23	3.20	2.60	1.18	1.80	1.52	1.20	3.00	2.50	1.00	4.40	4.40	1.07	7.20	6 72
10	1.228	2.40	1.54	1.20	.20	.166	1.14	.06	.05	1.20	.20	.160	1.11	4.80	4.32
10D	1.129	1.60	1.41	1.24	.82	.65	1.16	.16	.13	1.14	4.40	3.80	1.13	7.80	6.90
12	1.134	.02	.0175	1.19	.10	.084	1.20	.04	.033	1.16	.44	.37	1.12	2.40	2.10
12D	1.232	2.40	1.93	1.13	.16	.141	1.10	.10	.0909	1.15	2.80	2.40	1.21	3.80	3 40
Totals	....	105.18	91.41	....	54.48	48.401	....	31.56	26.84	....	46.86	42.85	....	66.80	58.82

TABLE IV. Number of bacteria per gram. Plot B, dry.

Depth, inches.	7—9	No. of bacteria.		7—23	No. of bacteria.		8—6	No. of bacteria.		8—20	No. of bacteria.		9—3	No. of bacteria.	
	Wt. of sample.	Per cc.	Per gm.	Wt. of sample.	Per cc.	Per gm.	Wt. of sample.	Per cc.	Per gm.	Wt. of sample.	Per cc.	Per gm.	Wt. of sample.	Per cc.	Per gm.
2	1.035	9.60	9.20	1.04	6.00	5.76	1.036	10.20	9.80	1.02	6.00	5.88	1.08	4.00	3.78
2D	1.024	30.40	29.50	1.042	9.60	9.20	1.035	1.60	1.035	1.0919	9.00	8.80	1.024	4.20	4.10
4	1.01	6.40	6.30	1.036	6.00	5.70	1.029	3.60	3.40	1.04	5.40	5.19	1.018	4.60	4.50
4D	1.034	8.00	7.70	1.035	6.00	5.70	1.03	11.40	11.06	1.026	4.80	4.60	1.048	4.20	4.00
6	1.02	4.80	4.70	1.029	.38	.36	1.02	4.20	4.10	1.084	3.60	3.40	1.034	3.40	3.20
6D	1.021	4.00	3.90	1.03	2.40	2.33	1.021	3.60	3.50	1.04	6.60	6.34	1.021	9.00	8.80
8	1.032	8.00	7.90	1.03	.26	.25	1.019	1.20	1.10	1.086	8.40	8.10	1.021	3.00	2.90
8D	1.08	5.60	5.43	1.034	.28	.27	1.021	4.20	4.10	1.03	6.00	5.82	1.04	3.00	2.88
10	1.028	2.40	2.30	1.033	.20	.19	1.034	1.20	1.10	1.028	6.00	5.80	1.06	3.40	3.20
10D	1.029	2.40	2.30	1.027	.36	.35	1.021	.12	.11	1.03	3.40	3.30	1.051	lost	lost
12	1.032	4.80	4.60	1.03	2.40	2.35	1.04	.44	.42	1.024	4.20	4.10	1.04	4.20	4.03
12D	1.034	1.60	1.50	1.045	.28	.26	1.029	.20	.19	1.029	.46	.44	1.051	lost	lost
Totals	....	88.00	85.33	....	34.16	32.72	....	41.96	39.91	....	63.86	61.77	....	43.00	41.39

TABLE V—PLOT A (sandy loam). Plowed March 18. Number of bacteria per cubic centimeter, per cent. of moisture, depth in inches, and temperature.

DATE.	Second inch.			Fourth inch.			Sixth inch.			Eighth inch.			Tenth inch.			Twelfth inch.			Plot.	Treatment.
	T.	B.	W.	T.	B.	W.	T.	B.	W.	T.	B.	W.	T.	B.	W.	T.	B.	W.		
Jul. 6......	22.0	11.4	20.0	19.6	11.4	21.2	18.9	9.0	22.4	18.1	10.80	23.0	18.0	2.40	23.0	18.0	4.20	24.0	A1	Undisturbed.
" 20......	20.5	8.4	24.8	21.0	12.0	24.3	20.9	9.6	26.0	20.8	14.40	28.8	20.4	6.00	25.8	19.9	8.60	28.1		
Aug. 3......	25.6	8.4	21.0	24.3	14.4	20.0	22.7	7.2	21.0	22.7	3.00	21.0	22.5	.16	21.0	22.4	.14	22.0		
" 17......	26.3	9.0	20.0	26.2	15.6	23.0	25.8	11.4	24.0	24.7	10.20	23.0	24.8	2.40	24.0	24.2	1.80	25.0		
" 31......	26.2	6.6	24.0	25.2	5.4	20.0	25.3	5.4	21.0	25.6	8.00	21.0	25.7	2.40	24.0	25.7	1.80	23.0		
Jul. 6......	22.0	14.4	21.5	19.6	13.0	22.0	18.0	24.0	25.0	18.1	19.20	25.5	18.0	9.00	25.7	18.0	3.00	26.8	A2	Plowed 2 inches.
" 20......	20.5	21.6	24.8	21.0	21.6	28.0	20.9	18.0	28.0	20.8	18.00	26.0	20.4	4.80	26.1	19.9	1.20	25.8		
Aug. 3......	25.6	14.4	20.0	24.3	4.8	20.0	22.7	13.2	20.0	22.7	6.00	22.0	22.5	.60	22.9	22.4	.26	24.0		
" 17......	26.3	13.2	25.0	26.2	11.4	24.0	25.8	10.2	24.0	24.7	5.40	26.0	24.3	3.40	26.0	24.2	2.40	28.0		
" 31......	26.2	8.4	18.0	25.2	6.6	21.0	25.3	5.4	22.0	25.6	9.60	25.0	25.7	3.00	24.0	25.7	.26	26.0		
Jul. 6......	22.0	15.0	18.9	19.6	x	21.1	18.9	19.2	22.5	18.0	11.40	23 9	18.0	9.60	24.8	18.0	9.00	25.0	A3	Plowed 4 inches.
" 20......	20.5	14.4	26.3	21.0	15.6	26.6	20.9	23.4	25.7	20.8	12.00	26.2	20.4	6.00	25.5	19.9	8.40	25.2		
Aug. 3......	23.6	6.0	18.0	24.3	4.8	22.0	22.7	6.0	23.0	22.7	4.80	24.0	22.5	4.80	24.0	22.0	1.80	25.0		
" 17......	21.8	6.6	25.0	26 2	12.0	25.0	25.8	7.8	24.0	24.7	3.60	25.2	24.8	5.40	25.0	24.2	.88	25.2		
" 31......	21.3	11.4	20.0	25.2	10 8	23.0	25.8	8.6	24.0	25.6	4.80	24.2	25.7	2.40	25.0	25.7	.40	24.9		
Jul. 6......	22.0	12.6	20.0	19.6	27.0	20.0	18.9	21.0	21.1	18.1	20.40	22.8	18.0	28.80	22.8	18.0	5.40	26.6	A4	Plowed 6 inches.
" 20......	20.5	18.2	23.7	21.0	16.8	24.5	20.9	26.4	26.0	20.4	12.00	26.7	20.4	10.80	26.2	19.9	6.60	26.0		
Aug. 3......	25.6	4.8	21.0	24.3	6.0	23.0	22.7	3.6	23.9	22.7	4.80	23.8	22.5	.60	24.0	22.4	.66	24.7		
" 17......	26.8	9.0	23.3	26.2	7.8	24.0	25.8	6.6	22.1	24.5	5.40	25.4	24.3	3.60	26.0	24.2	1.20	26.3		
" 31......	26.2	4.8	18.0	25.2	10.8	22.0	25.3	9.0	22.0	25.6	9.60	22.9	25.7	1.80	23.4	26.7	1.60	25.2		
Jul. 6......	22.0	27.0	20.6	19.6	38.4	20.8	18.9	32.4	21.4	18.1	9.96	21.2	18.0	40.07	23.4	18.0	11.40	24.5	A5	Plowed 8 inches.
" 20......	20.5	27.6	23.3	21.0	30.0	25.8	20.9	16.8	25.2	20.8	22.80	26.4	20.4	12.00	26.7	19.9	8.40	27.0		
Aug. 3......	25.6	8.4	19.0	24.3	4.8	24.0	23.7	7.2	24.1	22.7	15.60	25.5	22.5	3.60	25.4	22.4	9.60	26.1		
" 17......	26.3	4.8	21.0	26.2	6.0	23.0	25.8	8.4	25.0	24.5	12.00	25.4	24.3	4.80	15.0	25.2	6.60	26.0		
" 31......	26.2	4.2	20.0	25.2	7.2	20.0	25.3	4.2	21.0	25.6	3.60	21.4	25.7	8.60	22.6	25.7	2.50	23.9		
Jul. 6......	22.0	50.4	19.0	19.6	48.0	20.2	18.9	30.0	21.2	18.1	2.22	22.5	18.0	18.00	23.4	18.0	24.50	25.8	A6	Plowed 10 inches.
" 20......	20.5	20.4	21.2	21.0	13.2	23.0	20.9	27.6	23.6	20.8	10.80	23.2	20.4	4.80	24.3	19.9	6.00	24.6		
Aug. 3......	20.6	10.2	20.0	24.3	7.2	20.1	22.7	10.8	23.0	22.7	8.40	23.4	22.5	7.20	24.0	22.4	3.00	25.1		
" 17......	26.3	9.0	20.0	26.2	3.6	21.0	25.8	3.6	26.0	24.5	8.00	24.0	24.8	6.60	23.9	24.2	.32	25.0		
" 31......	26.2	8.0	20.0	25.2	3.5	21.2	25.3	8.5	22.0	25.6	2.90	23.0	25.0	6.50	23 7	25.7	.30	24.0		

x = spreading growth.

TABLE VI—PLOT A (sandy loam). Plowed March 18 and June 20. Number of bacteria per cubic centimeter, per cent. of moisture, depth in inches, and temperature.

DATE.	Second inch.			Fourth inch.			Sixth inch.			Eighth inch.			Tenth inch.			Twelfth inch.			Plot.	Treatment.
	T.	B.	W.	T.	B.	W.	T.	B.	W.	T.	B.	W.	T.	B.	W.	T.	B.	W.		
Jul. 6......	22.0	24.6	20.0	19.6	19.8	21.2	18.9	36.6	22.4	18.1	20.2	23.0	18.0	9.60	23.00	18.0	3.60	23.0	A1	Undisturbed.
" 20......	20.5	25.2	24.8	21.0	20.4	24.3	20.9	19.2	26.0	20.8	14.4	28.3	20.4	10.80	25.80	19.9	.60	28.5		
Aug. 3......	25.6	16.8	21.0	24.8	13.2	20.0	22.7	7.2	21.0	22.7	9.6	21.0	22.5	2.40	21.00	23.4	.74	22.0		
" 17......	26.3	9.0	20.0	26.2	15.6	23.0	25.8	11.4	24.0	24.7	10.2	23.0	24.3	2.40	24.00	24.2	1.80	25.0		
" 31......	26.2	6.6	24.0	25.2	5.4	20.0	25.3	5.4	21.0	25.6	6.0	21.0	25.7	2.40	24.00	25.7	1.80	23.0		
Jul. 6......	22.0	27.6	21.6	19.6	16.2	22.0	18.9	18.6	25.0	18.1	18.6	25.5	18.0	15.60	25.70	18.0	5.40	26.8	A2	Plowed 2 inches.
" 20......	20.5	21.8	24.8	21.0	24.0	28.0	20.9	12.0	28.0	20.8	6.0	26.0	20.4	3.60	26.10	19.9	3.60	25.8		
Aug. 3......	25.6	9.6	20.0	24.8	8.4	20.0	22.7	12.0	20.0	22.7	15.6	22.0	22.5	3.60	22.00	22.4	1.60	24.0		
" 17......	26.3	13.2	25.0	26.2	11.4	24.0	25.8	10.2	24.0	24.7	5.4	26.0	24.3	8.40	26.00	24.2	2.40	28.0		
" 31......	26.2	8.4	18.0	25.2	6.6	21.0	25.8	5.4	22.0	25.6	9.6	25.0	25.7	3.00	24.00	25.7	.26	26.0		
Jul. 6......	22.0	22.8	18.8	19.6	19.8	21.0	18.9	13.2	22.5	18.1	16.2	23.0	18.0	7.80	24.80	18.0	1.80	25.1	A3	Plowed 4 inches.
" 20......	20.5	12.0	26.8	21.0	32.4	26.6	20.9	18.2	25.7	20.8	8.4	26.2	20.4	6.00	25.50	19.9	2.40	25.2		
Aug. 3......	25.6	6.0	21.0	24.8	8.4	23.4	22.7	7.2	24.9	22.7	5.4	25.0	22.5	1.20	26.00	22.4	2.40	24.9		
" 17......	26.3	6.0	20.0	26.2	4.8	23.0	21.3	10.2	24.9	24.2	3.0	24.3	24.3	.46	25.90	24.2	.66	26.0		
" 31......	26.7	6.6	23.0	25.2	3.0	19.0	25.3	3.6	23.0	25.6	4.0	23.4	25.7	.30	26.00	21.7	.30	25.4		
Jul. 6......	22.0	15.0	22.3	19.6	15.6	22.9	18.9	21.6	25.4	18.1	16.2	26.5	18.0	5.40	25.70	18.0	4.80	27.0	A4	Plowed 6 inches.
" 20......	20.5	20.4	27.5	21.0	27.6	27.0	20.9	46.8	26.5	20.8	lost	25.8	20.4	8.40	25.00	19.9	4.80	25.4		
Aug. 3......	25.6	11.4	21.0	24.8	9.6	22.0	22.7	13.2	22.9	22.7	12.6	23.0	22.5	.46	23.70	22.4	2.40	25.0		
" 17......	26.3	13.2	24.0	26.5	6.6	24.5	25.8	12.6	24.4	24.7	7.8	25.9	24.3	4.20	26.30	24.2	3.00	26.0		
" 31......	26.2	6.1	17.0	25.2	6.1	22.0	25.3	8.4	23.4	25.6	3.0	25.2	25.7	3.00	25.00	21.7	5.00	27.0		
Jul. 6......	22.0	46.2	19.2	19.6	24.6	22.2	18.9	15.6	24.0	18.1	19.2	24.9	18.0	10.80	25.10	18.0	4.80	26.0	A5	Plowed 8 inches.
" 20......	20.5	15.6	25.7	21.0	14.4	25.0	20.9	26.4	26.0	20.8	31.2	25.9	20.4	12.00	26.10	19.9	1.20	27.3		
Aug. 3......	25.6	3.6	19.0	24.8	23.4	26.7	22.7	7.8	25 8	22.7	10.8	26.0	22.5	15.00	27.04	22.4	6.00	27.1		
" 17......	26.3	12.0	20.0	26.5	3.6	21.8	25.8	9.6	22.1	24.7	6.0	25.0	24.3	6.60	26.20	24.2	4.20	26.0		
" 31......	26.2	8.4	24.3	25.2	4.9	25.0	25.3	6.0	25.0	25.6	7.8	26.1	25.7	4.80	24.80	21.7	1.80	23.2		
Jul. 6......	22.0	19.2	19.6	19.6	17.4	22.1	18.9	9.6	22.9	18.1	16.8	23.7	18.0	7.20	23.10	11.8	8.40	24.2	A6	Plowed 10 inches.
" 20......	20.5	12.0	25.4	21.0	14.4	24.6	20.9	19.2	24.9	20.8	4.2	26.9	20.4	13.20	20.20	19.9	8.40	26.5		
Aug. 3......	25.6	4.2	19.0	24.8	4.8	21.0	22.7	7.8	22.4	22.7	5.4	23.0	22.5	6.00	24.00	22.3	6.00	25.0		
" 17......	26.3	4.8	20.0	26 5	10.8	21.4	25.8	8.4	22.0	24.7	4.8	24.0	24.3	9.60	24.30	24.2	4.80	25.2		
" 31......	26.2	7.2	20.0	25.2	7.2	21.0	25.3	6.0	21.5	25.6	6.0	25.0	25.7	5.40	24.00	21.7	4.20	25.2		

TABLE VII—PLOT B (silt loam). Plowed March 18. Number of bacteria per cubic centimeter, per cent. of moisture, depth in inches, and temperature.

DATE.	Second inch.			Fourth inch.			Sixth inch			Eighth inch.			Tenth inch.			Twelfth inch.			Plot.	Treatment.
	T.	B.	W.	T.	B.	W.	T.	B.	W.	T.	B.	W.	T.	B.	W.	T.	B.	W.		
Jul. 9..	25.4	25.20	17.0	23.1	36.0	17.9	22.9	8.40	19.0	22.3	2.40	20.0	21.9	2.40	20.0	21.0	7.20	28.0	B1	Undisturbed.
" 23..	28.0	4.80	18.0	26.0	13.2	18.4	24.9	.80	19.0	24.9	2.40	19.9	25.0	.10	26.0	24.7	.18	25.0		
Aug. 6..	28.6	2.40	20.0	27.3	1.8	20.9	26.7	.40	24.0	26.8	.24	26.8	24.0	.02	26.9	26.6	.02	26.0		
" 20..	21.8	7.20	26.0	20.2	4.8	26.4	19.8	6.00	26.8	19.7	3.00	27.0	20.8	6.00	27.2	20.3	1.80	27.0		
Sep. 3..	22.0	10.20	26.0	20.0	5.4	27.0	20.7	15.60	27.0	20.9	4.20	29.0	21.8	2.40	20.9	22.0	1.80	23.0		
Jul. 9..	25.4	18.00	25.0	23.1	40.8	25.0	22.9	19.20	27.0	22.3	4.80	27.4	21.9	4.80	27.8	21.0	2.80	26.9	B2	Plowed 2 inches.
" 23..	28.0	.84	10.0	26.0	4.8	24.6	24.9	4.80	13.0	24.9	.12	16.0	25.0	3.00	17.0	24.7	.08	11.0		
Aug. 6..	28.6	.38	15.0	27.3	.7	18.0	26.7	.14	20.0	26.8	.18	23.0	26.9	.08	20.0	26.6	.02	21.0		
" 20..	21.3	6.00	23.0	20.2	6.6	lost	19.8	5.40	20.0	19.7	.26	20.0	20.3	.38	19 0	20.8	.38	26.0		
Sep. 3..	22.0	4.80	18.0	20.0	7.2	21.0	20.7	5.40	lost	20.9	6.00	20.0	21.8	4.80	22.0	22.0	.18	16.0		
Jul. 9..	25.4	19.20	18.0	23.1	15.6	20.0	22.9	7.20	19.0	22.3	7.20	17.0	21.9	4.80	20.0	21.0	3.60	26.0	B3	Plowed 4 inches.
" 23..	28.0	6.00	15.4	26.0	10.0	17.0	24.9	.04	17.0	24.9	.06	11.0	25.0	.00	11.0	24.7	.01	29.0		
Aug. 6..	28.6	3.60	18.0	27.3	4.2	17.0	26.7	.28	20.0	26.8	.68	21.0	26.9	.58	21.0	26.6	.08	28.0		
" 20..	21.3	14.40	23.0	20.2	16.8	17.6	19.8	.60	19.0	19.7	.16	22.0	20.3	1.12	23.0	20.3	.21	21.0		
Sep. 3..	22.0	7.20	18.0	20.0	6.0	20.0	20.7	10.80	19.0	20.9	3.60	17.0	21.8	3.60	20.0	22.0	.12	26.0		
Jul. 9..	25.4	3.60	16.0	23.1	28.8	20.0	22.9	24.00	17.0	22.3	3 60	21.0	21.9	4.20	18.0	21.0	1.20	22.0	B4	Plowed 6 inches.
" 23..	28.0	6.00	18.2	26.0	6.0	17.0	24.9	3.60	12.0	24.9	.16	15.0	25.0	.08	15.0	24.7	.08	11.0		
Aug. 6..	28.6	.18	22.0	27.3	1.8	19.0	26.7	4.20	20.0	26.8	.02	18.0	26.9	.24	20.0	26.6	.06	23.0		
" 20..	21.3	5.40	21.0	20.2	11.4	27.0	19.8	4.80	22.0	19.7	.36	23.0	20.3	.18	18.0	20.3	.62	23.0		
Sep. 3..	22.0	5.40	16.0	20.0	10.8	20.0	20.7	8.40	17 0	20.9	4.80	21.0	21.8	3.60	18.0	22.0	3.60	22.0		
Jul. 9..	25.4	30.00	16.0	23.1	30.0	17.0	22.9	4.20	22.0	22.3	8.40	20.7	21.9	6.00	19.0	21.0	4.80	22.0	B5	Plowed 8 inches.
" 23..	28.0	.04	20.0	26.0	4.8	13.0	24.9	48.00	18.2	24.9	3.60	10.0	25.0	.06	10.0	24.7	.04	12.0		
Aug. 6..	28.6	2.40	19.0	27.3	2.4	18.0	26.7	3.00	19.0	26.8	.16	19.0	26.9	2.40	17.0	26.6	1.80	21.0		
" 20..	21.3	6.00	21.0	20.2	30.6	22.0	19.8	10.20	23.0	19.7	3.00	23.0	20.3	2.22	24.0	20.3	.34	23.0		
Sep. 3..	22.0	7.80	16.0	20.0	9.0	17.0	20.7	4.80	20.0	20.9	3.00	20.7	21.8	3.00	19.0	22.0	3.00	22.0		
Jul. 9..	25.4	26.40	19.0	23.1	33.6	20.0	22.9	34.80	20.0	22.3	27.60	20.0	21.9	7.20	20.0	21.0	4.80	22 0	B6	Plowed 10 inches.
" 23..	28.0	2.40	19.0	26.0	2.4	18.0	24.9	3.60	15.0	24.9	.32	18.0	25.0	.10	19.4	24.7	.12	20.4		
Aug. 6..	28.6	1.80	19.0	27.3	6.0	20.0	26.7	1.00	18.0	26.8	.12	19.0	26.9	.06	23.0	26.6	.44	21.0		
" 20..	21.3	6.60	20.2	20.8	10.7	17.0	19.8	4.20	17.0	19.7	4.80	20.3	20.3	3.00	23.0	20.8	1.80	24.0		
Sep. 3..	22.0	4.80	19.0	20.0	7.3	20.0	20.7	4.20	20.0	22.9	5.40	20.0	21.8	4.20	20.0	22 0	2.40	22.0		

TABLE VIII—PLOT B (silt loam). Plowed March 18 and June 20. Number of bacteria per cubic centimeter, per cent. of moisture, depth in inches, and temperature.

DATE.	Second inch:			Fourth inch.			Sixth inch.			Eighth inch.			Tenth inch.			Twelfth inch.			Plot.	Treatment.
	T.	B.	W.	T.	B.	W.	T.	B.	W.	T.	B.	W.	T.	B.	W.	T.	B.	W.		
Jul. 9..	25.4	31.2	17.0	23.1	38.40	17.0	22.9	13.20	17.0	22.3	8.40	19.0	21.9	9.60	20.0	21.0	4.80	23.0	B1	Undisturbed.
" 23..	28.0	6.0	12.0	26.0	7.20	18.4	24.8	.30	19.0	24.9	3.60	18.0	25.0	3.60	26.0	24.7	.10	25.0		
Aug. 6..	28.6	2.4	16.0	27.3	1.80	19.0	26.7	.40	24.0	·26.8	.24	21.0	26.9	.02	20.0	26.6	.02	24.0		
" 20..	21.3	7.2	26.0	20.2	4.80	21.0	19.8	6.00	25.0	19.7	3.00	20.0	20.3	6.00	26.0	20.3	1.80	25.0		
Sep. 3..	22.0	10.2	11.0	20.0	5.40	17.0	20.7	15.60	17.0	20.9	4.20	19.0	21.8	2.40	20.0	22.0	1.80	23.0		
Jul. 9..	25.4	16.8	18.0	23.1	26.46	15.1	22.0	19.20	15.2	22.3	4.80	20.0	21.9	2.40	22.0	21.0	2.40	16.0	B2	Plowed 2 inches.
" 23..	28.0	13.2	10.0	26.0	7.20	24.6	24.9	2.00	13.0	24.9	.30	16.0	25.0	.12	17.0	24.7	.16	11.0		
Aug. 6..	28.6	3.8	15.0	27.3	7.00	18.0	26.7	.14	20.0	26.8	1.80	23.0	26.9	.08	20.0	26.6	.08	21.0		
" 20..	21.3	6.0	23.0	20.0	6.60	19.0	19.8	5.40	20.0	19.7	.26	20.0	20.3	.38	19.0	20.3	.38	26.0		
Sep. 3..	22.0	4.8	18.0	20.0	7.20	15.1	20.7	5.40	lost	20.9	6.00	20.0	21.8	.48	22.0	22.0	1.80	16.0		
Jul. 9..	25.4	26.4	17.0	23.1	30.00	20.0	22.9	7.20	21.0	22.3	6.00	20.0	21.9	3.60	28.0	21.0	.60	23.0	B3	Plowed 4 inches.
" 23..	28.0	6.0	13.6	26.0	9.60	13.7	24.9	.16	23.0	24.9	12.00	13.8	25.0	.36	12.0	24.7	.02	18.0		
Aug. 6..	28.6	18.2	19.0	27.3	.28	14.0	26.7	.30	18.0	26.8	.58	26.0	26.9	.20	19.0	26.6	.72	22.0		
" 20..	21.3	10.2	18.0	20.2	18.00	20.0	19.7	14.40	23.0	19.7	4.80	23.0	20.8	3.60	23.0	20.3	.30	23.0		
Sep. 3..	22.0	7.2	18.0	20.0	10.80	17.0	20.7	4.20	21.0	20.9	5.40	23.0	21.8	3.60	23.0	22.0	4.80	23.0		
Jul. 9..	25.4	39.6	16.0	23.1	40.80	18.0	22.9	7.20	20.0	22.3	4.80	20.0	21.9	2.40	19.0	21.0	.60	20.0	B4	Plowed 6 inches.
" 23..	28.0	3.6	16.0	26.0	19.20	25.0	24.9	.08	15.0	24.9	2.40	19.0	25.0	.08	21.0	24.7	.30	14.2		
Aug. 6..	28.6	7.2	16.0	27.3	6.00	20.0	26.7	.96	23.0	26.8	.40	18.0	26.9	.04	22.0	26.6	.12	21.0		
" 20..	21.3	18.2	21.0	20.2	17.40	25.0	19.8	11.40	21.0	19.7	4.20	16.0	20.3	1.80	23.4	20.3	1.40	24.0		
Sep. 3..	22.0	7.2	19.0	20.0	12.00	21.0	20.7	4.80	lost	20.9	2.40	25.0	21.8	3.60	22.9	22.0	3.00	23.0		
Jul. 9..	25.4	16.8	18.0	23.1	27.60	17.0	22.9	10.80	21.0	22.3	7.20	23.0	21.9	1.20	23.0	21.0	2.40	23.0	B5	Plowed 8 inches.
" 23..	28.0	6.0	24.0	26.0	8.40	22.0	24.9	7.20	18.0	24.9	3.60	15.0	25.0	.14	18.0	24.7	.02	23.0		
Aug. 6..	28.6	4.8	20.0	27.3	3.60	29.0	26.7	18.00	18.0	26.8	.32	16.0	26.9	.04	21.0	26.6	.08	21.0		
" 20..	21.3	9.6	29.0	20.2	18.60	24.0	19.8	11.40	23.0	19.7	.12	27.0	20.3	.30	27.0	20.3	1.20	25.0		
Sep. 3..	22.0	4.8	17.0	20.0	5.40	20.0	20.7	6.60	21.0	20.9	9.00	20.0	21.8	10.20	24.0	22.0	7.20	23.0		
Jul. 9..	25.4	21.6	19.0	23.1	33.60	21.0	22.9	15.60	20.0	22.3	7.20	25.0	21.9	7.00	22.0	21.0	3.60	23.0	B6	Plowed 10 inches.
" 23..	28.0	6.0	24.0	26.0	4.80	18.0	24.9	3.60	15.0	24.9	.04	10.0	25.0	.04	21.0	24.7	.04	12.0		
Aug. 6..	28.6	3.6	15.0	27.7	4.80	18.0	26.7	3.60	18.0	26.8	7.20	18.0	26.9	5.40	20.0	26.6	1 20	19.0		
" 20..	21.3	5.4	28.0	20.2	9.60	28.0	19.8	10.20	23.0	19.7	14.40	28.0	20.8	8.40	25.0	20.3	2.40	26.0		
Sep. 3..	22.0	7.8	16.0	20.0	7.20	18.0	20.7	9.60	20.0	20.9	8.40	20.0	21.8	4.80	19.0	22.0	.30	20.0		

A COMPARISON OF THE GRAVIMETRIC AND VOLUMETRIC METHODS.

Tables I to IV give the comparative results obtained by gravimetric and volumetric methods. The samples were taken by means of the sampler described above. One cubic centimeter of soil was taken each time, placed in a sterile test-tube and weighed on an analytic balance. In every case duplicate samples were obtained and analyzed. In the following tables the weight of each sample is given in the first column, the number of bacteria per cubic centimeter is given in the second, and the number of bacteria per gram is given in the third column.

A glance at tables I to IV will show a variation in weights of samples varying in table I from 1.19 to 1.4 grams per cubic centimeter, from 0.965 to 1.14 grams in table II, from 1.021 to 1.232 grams in table III, and from 1.01 grams to 1.035 grams in table IV. The comparison also shows remarkable differences in weight between many samples and their duplicates, which were taken side by side. For instance, in table IV the fourth inch gives 1.01 grams while the duplicate gives 1.034. In the sandy soil (table II) the difference becomes more marked, showing in the twelfth inch a difference of 0.113 of a gram.

In tables I to IV the number of bacteria per cubic centimeter and per gram shows, in duplicate samples of soil, variations which are somewhat proportionate to the variations in weight of samples. These variations in quantitative findings represent the inaccuracy which is due to the volumetric method of taking soil samples. It may be assumed that such variations or inaccuracies will always occur from soil samples which are measured in terms of cubic centimeters. However, in general comparative soil bacteriological work these variations in number of bacteria, due to the volumetric method of procedure, may not be greater than those variations which might occur as a result of differences in specific gravities of different samples of soil, should the soil samples be taken by the gravimetric method. For instance, two types of soil, Marshall silt loam and sandy loam, were used in this work. The volume weight of the silt loam soil is 1.11 and the volume weight of the sandy loam is 1.35. Their weights stand in the ratio of 1:1.21; that is, an acre-foot of the sandy loam weighs 1.21 times as much as an acre-foot of the silt loam. Therefore, should samples be collected from the above types of soil by the gravimetric method and the comparative results expressed as so many bacteria per gram, the number of bacteria in an acre-foot of the sandy loam would in reality be compared with the number of bacteria in 1.21 acre-feet of the silt loam.

In quantitative bacteriological work, when comparative results are desired, the volumetric method has the following possible advantages over the gravimetric method:

1. It is more convenient.
2. It allows less chance for contamination.
3. It represents more accurately an aliquot part of an acre-foot of soil.

The last advantage appears to be true because of the difference in specific gravity of soils.

Drying Effect.—When we compare tables I and II with III and IV, we find no appreciable difference in results between those soil samples which were allowed to dry twenty-four hours before inoculation and those from which inoculations were made immediately after collection.

TABLE IX—PLOT A. Summarized total number bacteria given in table V.

DEPTH.	A1. Undisturbed.	A2. Plowed 2 in.	A3. Plowed 4 in.	A4. Plowed 6 in.	A5. Plowed 8 in.	A6. Plowed 10 in.
2 inches	43.80	72.00	53.40	44.40	72.00	98.00
4 "	58.80	57.40	43.20	68.40	80.40	75.50
6 "	42.60	70.80	60.00	66.60	69.00	85.50
8 "	46.40	58.20	36.60	52.20	63.96	47.30
10 "	13.86	20.80	28.20	45.60	64.07	43.10
12 "	11.54	7.12	20.48	15.46	38.50	34.12
Totals	216.50	286.82	241.68	292.66	393.98	383.52

TABLE X—PLOT A. Summarized total number of bacteria given in table VI.

DEPTH.	A1. Undisturbed.	A2. Plowed 2 in.	A3. Plowed 4 in.	A4. Plowed 6 in.	A5. Plowed 8 in.	A6. Plowed 10 in.
2 inches	82.20	80.60	53.40	66.10	85.80	47.40
4 "	74.40	66.60	68.40	65.50	70.90	54.60
6 "	79.80	58.20	47.40	102.60	65.40	51.00
8 "	60.40	55.20	37.00	39.60	75.00	37.20
10 "	27.60	29.20	15.76	21.46	49.20	41.40
12 "	8.54	13.26	7.56	20.00	18.00	31.80
Totals	332.94	308.06	229.52	315.26	364.30	263.40

TABLE XI—PLOT B. Summarized total number bacteria given in table VII.

DEPTH.	B1. Undisturbed.	B2. Plowed 2 in.	B3. Plowed 4 in.	B4. Plowed 6 in.	B5. Plowed 8 in.	B6. Plowed 10 in.
2 inches	49.80	30.02	50.40	20.58	46.24	42.00
4 "	61.20	60.10	52.60	58.80	76.80	60.00
6 "	30.70	34.94	18.92	45.00	70.20	47.80
8 "	12.24	11.36	11.70	8.94	18.16	38.24
10 "	10.92	13.06	10.10	8.30	13.68	14.56
12 "	11.00	3.46	4.02	5.51	9.98	9.56
Totals	175.86	152.94	147.74	147.18	235 06	212.16

TABLE XII—PLOT B. Summarized total number bacteria given in table VIII.

DEPTH.	B1. Undisturbed.	B2. Plowed 2 in.	B3. Plowed 4 in.	B4. Plowed 6 in.	B5. Plowed 8 in.	B6. Plowed 10 in.
2 inches	57.00	44.60	63.00	70.80	42.00	44.40
4 "	57.60	54.40	68.68	95.40	63.60	60.00
6 "	35.50	32.14	26.26	24.44	54.00	42.60
8 "	19.44	18.16	28.78	14.20	20.24	37.24
10 "	21.62	3.46	11.36	7.92	11.88	25.64
12 "	8.52	4.82	6.44	5.42	10.90	7.54
Totals	199.68	152.58	204.52	218.18	202.62	217.42

TABLE XIII.

DATE.	Plot.	Ammonia, parts per million.	Nitrites, parts per million.	Gas production.		
				Glucose bouillon, in cc.	Lactose bouillon, in cc.	Saccharose bouillon, in cc.
Jul. 20	A1	25	75	0.00	0.00	0.0
" 20	A2	50	75	7.70	1.25	0.0
" 20	A3	50	75	4.50	1.75	0.9
" 20	A4	1	40	5.80	0.00	0.0
" 20	A5	75	1	5.80	0.00	0.0
" 20	A6	75	14	5.50	0.00	0.0
Totals	......	276	280			
Aug. 3	A1	50	45	0.00	0.00	0.0
" 3	A2	25	50	0.00	0.00	0.0
" 3	A3	250	75	0.00	0.00	0.0
" 3	A4	75	30	0.00	0.00	0.0
" 3	A5	45	40	0.00	0.00	0.0
" 3	A6	75	20	0.00	0.00	0.0
Totals	......	520	260			
Aug. 17	A1	30	145	3.00	1.50	5.5
" 17	A2	300	111	1.75	1.25	5.0
" 17	A3	1	x	3.00	1.75	7.0
" 17	A4	x	100	2.00	1.10	5.0
" 17	A5	300	x	2.50	1.00	7.0
" 17	A6	800	x	1.50	1.50	9.5
Totals	......	1,431	356			
Aug. 31	A1	700	200	7.50	8.50	0.0
" 31	A2	750	150	8.15	9.00	0.0
" 31	A3	1	75	6.00	2.50	0.0
" 31	A4	1,500	80	6.00	9.50	0.0
" 31	A5	1,000	65	2.50	.50	0.0
" 31	A6	2,000	110	8.50	1.50	0.0
Totals	......	5,951	680			

Total nitrites, 1576; total ammonia, 8178.

TABLE XIV.

DATE.	Plot.	Ammonia, parts per million.	Nitrites, parts per million.	Gas production.		
				Glucose bouillon, in cm.	Lactose bouillon, in cm.	Saccharose bouillon, in cm.
Jul. 20	A1	25	30	0.00	0.00	0.00
" 20	A2	50	30	7.00	1.25	0.00
" 20	A3	5	17	7.50	0.00	0.00
" 20	A4	50	10	8.50	0.00	0.00
" 20	A5	1	15	9.80	0.00	0.00
" 20	A6	100	11	10.00	lost	0.00
Totals	......	231	113			
Aug. 3	A1	25	15	0.00	0.00	0.00
" 3	A2	50	20	0.00	0.00	0.00
" 3	A3	25	17	0.00	0.00	0.00
" 3	A4	50	20	0.00	0.00	0.00
" 3	A5	10	11	3.25	0.00	0.00
" 3	A6	90	11	0.00	lost	3.00
Totals	......	250	94			
Aug. 17	A1	30	145	3.00	1.50	5.00
" 17	A2	300	111	1.75	1.25	7.25
" 17	A3	700	x	1.50	1.00	8.00
" 17	A4	x	100	2.00	1.50	9.50
" 17	A5	lost	x	1.00	1.25	10.00
" 17	A6	800	x	1.50	1.00	10.00
Totals	......	1,830	356			
Aug. 31	A1	700	150	7.50	8.50	0.00
" 31	A2	750	140	8.15.	9.90	0.00
" 31	A3	500	90	10.50	2.00	0.00
" 31	A4	700	40	8.00	1.00	0.00
" 31	A5	1,000	75	1.00	.50	0.00
" 31	A6	950	30	10.00	9.50	0.00
Totals	......	4,600	525			

Total nitrites, 1088; total ammonia, 6911.

TABLE XV.

Date.	Plot.	Ammonia, parts per million.	Nitrites, parts per million.	Gas production.		
				Glucose bouillon, in cm.	Lactose bouillon, in cm.	Saccharose bouillon, in cm.
Jul. 23	B1	25	15	0.00	0.00	0.00
" 23	B2	50	27	0.00	2.00	0.00
" 23	B3	100	20	4.00	3.00	0.00
" 23	B4	50	11	0.00	1.50	1.00
" 23	B5	50	12	1.00	5.00	0.00
" 23	B6	100	9	1.50	7.00	0.00
Totals	......	375	94			
Aug. 6	B1	x	17	4.25	1.75	7.25
" 6	B2	x	17	4.00	1.50	8.00
" 6	B3	1	10	4.25	1.20	7.50
" 6	B4	1	6	0.00	0.00	0.00
" 6	B5	1	2	0.00	1.25	0.00
" 6	B6	9	8	0.00	.50	7.70
Totals	......	12	60			
Aug. 20	B1	100	150	3.25	3.00	0.00
" 20	B2	300	145	0.00	0.00	0.00
" 20	B3	90	145	3.50	1.25	7.00
" 20	B4	400	x	0.00	0.00	0.00
" 20	B5	600	120	T	T	0.00
" 20	B6	x	75	0.00	0.00	0.00
Totals	......	1,490	635			
Sep. 3	B1	2,000	20	11.00	7.00	0.00
" 3	B2	0	25	7.00	4.00	0.00
" 3	B3	5,000	30	55.00	3.50	0.00
" 3	B4	6,000	4	8.50	4.00	0.00
" 3	B5	8,000	7	8.50	45.00	0.00
" 3	B6	6,000	2	12.00	8.50	0.00
Totals	......	27,000	88			

Total nitrites, 877; total ammonia, 28,877.

TABLE XVI.

DATE.	Plot.	Ammonia, parts per million.	Nitrites, parts per million.	Gas production.		
				Glucose bouillon, in cm.	Lactose bouillon, in cm.	Saccharose bouillon, in cm.
Jul. 23	B1	25	10	1.00	0.00	0.00
" 23	B2	50	10	1.50	0.00	0.00
" 23	B3	75	x	3.50	0.00	0.00
" 23	B4	25	5	0.00	0.00	0.00
" 23	B5	50	8	0.00	9.00	8.00
" 23	B6	100	6	0.00	0.00	1.50
Totals	......	325	39			
Aug. 6	B1	x	15	4.25	1.75	7.25
" 6	B2	x	16	4.00	1.50	8.00
" 6	B3	1	9	4 25	1.00	9.40
" 6	B4	4	11	3.75	1.40	8.40
" 6	B5	x	4	4.00	1.50	5.75
" 6	B6	10	7	4.10	1.00	8.75
Totals	......	15	62			
Aug. 20	B1	100	185	3 25	3.00	0.00
" 20	B2	300	145	0.00	0.00	0.00
" 20	B3	30	145	5.00	0.00	0.00
" 20	B4	0	175	0.00	1.00	0.00
" 20	B5	8	120	0.00	2.00	0.00
" 20	B6	lost	90	0.00	0.00	0.00
Totals	......	438	860			
Sep. 3	B1	2,000	20	11.00	7.00	0.00
" 3	B2	0	25	7.00	4.00	0.00
" 3	B3	6,000	5	8.50	8.50	0.00
" 3	B4	8,000	7	8.00	2.00	0.00
" 3	B5	8,500	7	9.00	10.00	0.00
" 3	B6	9,000	6	8 00	9.50	0.00
Totals	......	33,500	70			

Total nitrites, 1081; total ammonia, 34,278.

NUMBER OF BACTERIA.

Tables V to VIII show a great variation between the number of bacteria at the beginning of the experiment and at the close. This condition holds in all subplots in both sandy and silt loam soils. This may be due to the lessening amount of food available to the bacteria because the temperature, moisture and air remain throughout the experiment within the limit of experimental variation.

Tables V to VIII show exceptionally high numbers of bacteria, sometimes in the surface six inches, and again at the depth of twelve inches. The extra large numbers which are found in some samples from the first six inches of soil were nearly always attributable to manure or quantities of organic matter, while those in the subsoil were usually near some burrow, or at times were due to the presence of a heavy, decaying root.

By comparing tables I to X in the preliminary experiments (part I), it was found that the total number of bacteria in the surface foot of soil is increased by the deeper plowing. This fact is also shown in tables IX to XII (part II), which contain the sum totals of tables V to VIII. In the Marshall silt loam there was also a slight advantage in regard to the total number of bacteria in favor of the plots which were replowed on June 20.

AMMONIA PRODUCTION.

Tables XIII to XVI show the relative amounts of ammonia produced in the different plots. The total amount produced in the silt loam soil exceeded that produced in the sandy loam soil. A comparison of the tables will show that the amount of ammonia produced in the different plots, both in the sandy loam and the silt loam, increased with the depth of plowing. The depth of plowing seems to have greater effect upon the ammonia production in the more tenacious silt soil.

This increase in ammonia production was not regular, but in general conformed to the depth of stirring, although the amount produced varied greatly from week to week. Excess of moisture showed a tendency to lessen the amount of ammonia produced.

Occasionally only a trace of ammonia was present, as will be seen in table XIII, subplot A4, on July 20, and again in subplots A3 and A4, on August 17. This irregularity is found in all the plots. In many cases where these low yields occurred the medium was overgrown with an organism which produced a greenish pigment similar to that of *Ps. fluorescens liquefaciens*. These bacteria seemed to predominate during an excessively moist period.

REDUCTION OF NITRATES.

Denitrification, or the reduction of nitrates to nitrites, with the final liberation of nitrogen gas, may accompany the destructive processes of nitrogen compounds. Some of the ammonia compounds are broken down, liberating free nitrogen, while at the same time the nitrates which may have been formed are reduced to nitrites. These may be broken down into simpler substances, thus releasing free nitrogen.

The results of the experiments testing denitrification are given in tables XIII to XVI, under the heading "Nitrites," expressed as parts per million. In general, the amount of nitrites produced was in inverse proportion to the amounts of ammonia produced. In general, the production of nitrites decreased as the depth of plowing increased.

SUMMARY.

The results of these preliminary experiments suggest the following conclusions:

1. Deep plowing (eight to ten inches) tends to increase the number of soil bacteria in both sandy and silt soils.

2. Deep plowing tends to increase bacterial activity. More ammonia is produced.

3. Deep plowing tends to decrease denitrification or the reduction of nitrates and the liberation of free nitrogen.

4. The volumetric method of quantitative bacteriological soil analysis has the following possible advantages over the gravimetric method: (*a*) It is more simple and convenient; (*b*) there is less danger of contamination; (*c*) the results are placed on a more accurate basis for comparison. The volumetric method can be used to advantage when comparative results are desired.

5. Increased soil temperature increases bacterial activity.

6. An excess of moisture in soil reduces the number of bacteria and is detrimental to bacterial activity.

7. The maximum number of bacteria is found within the fifth and sixth inches. Either side of this zone the numbers of bacteria decrease.

8. Due to certain conditions, different species of bacteria are present in soil, at different times in predominating numbers.

9. Bacterial life and activity seem to rise and fall with more or less regularity. These periods of maximum and minimum activity are to a certain extent independent of moisture and temperature and are possibly due to the presence of bacterial by-products.

THE FOLLOWING BULLETINS

ARE AVAILABLE FOR DISTRIBUTION TO THOSE RESIDENTS OF KANSAS WHO MAY DESIRE THEM:

No. 12....Preliminary Experiments with Fungicides for Stinking Smut of Wheat.
No. 13....Experiments with Oats.
No. 15....Additional Experiments and Observation on Oat Smut.
No. 16....Experiments with Sorghum and with Sugar Beets.
No. 43....Experiments with Sorghum and with Sugar Beets.
No. 52....Kansas Weeds—Preliminary Circular on Distribution.
No. 120....Tests of Forest Trees.
No. 121....Treatment and Utilization of Flood-damaged Lands.
No. 122....Blackleg and Vaccination.
No. 129....Kansas Mammals in their Relation to Agriculture.
No. 136....Press Bulletins Nos. 125-151.
No. 137....Variations in the Test of Separator Cream.
No. 138....Effect of Bacteria in Wash-water of Butter.
No. 139....The Study of Corn.
No. 140....Milking Machines.
No. 141....Commercial Seeds of Brome-grass and of English and Kentucky Blue-grasses: Adulterants and Substitutes and their Detection.
No. 142....The Value of Oil in Road Improvement.
No. 143....Disposal of Dairy and Farm Sewage, and Water Supply.
No. 144....Small-grain Crops.
No. 145....Spraying.
No. 148....Law Regulating the Sale of Commercial Fertilizers.
No. 149....Prevention of Sorghum and Kafir-corn Smut.
No. 150....The Hen's Place on the Farm.
No. 151....Alfalfa Breeding.
No. 152....The Pocket Gopher.
No. 153....Deterioration of Red Texas Oats in Kansas.
No. 154....The Mound-building Prairie Ant.
No. 155....Alfalfa.
No. 158....Analyses of Registered Feeding Stuffs.
No. 159....Analyses of Eggs.
No. 160....Cow-peas.
Circular No. 1.—Treating Seed-corn to Protect it from Burrowing Animals.
Circular No. 2.—Preparing Land for Wheat.

The Bulletins of the Experiment Station are sent free to applicants. Farmers are invited to send the names of others who would value them and samples will be sent, with return cards upon which applications for future issues may be made.

Address: AGRICULTURAL EXPERIMENT STATION,
Manhattan, Kan.

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Kansas State Agricultural College.

EXPERIMENT STATION.—Bulletin 162.

Ed. H. Webster, *Director*.

FARM BULLETIN.

Dairy Husbandry Department.

J. C. Kendall, *Dairyman in Charge*.

The Marketing of Eggs.

BY

A. G. Philips, *Assistant, in Charge Poultry Husbandry*.

MANHATTAN, KAN.,
December, 1909.

DAIRY HUSBANDRY DEPARTMENT.

J. C. KENDALL	Dairyman in Charge.
——— ———	Assistant Dairyman.
A. B. NYSTROM	Assistant in Dairy Manufactures.
A. G. PHILIPS	Assistant in Charge of Poultry Husbandry.
A. MIYAWAKI	Assistant in Experimental Dairying.
W. A. LAMB	Superintendent Poultry Plant.
O. A. HAAGENSEN	Herdsman.

WORK OF THE DAIRY DEPARTMENT.

The work of the Dairy Department is divided into two general groups: Dairying and Poultry Raising. The Dairy group is again divided into Farm Dairying and Dairy Manufactures. The lines of investigation which are being conducted are: (1) Feeding and care of dairy stock; (2) Growing feeds for dairy stock, including storing in barn and silo; (3) Handling of milk and cream for market purposes; (4) Manufacture of butter, cheese, ice-cream, etc.; (5) Feeding and breeding poultry; (6) Incubation and brooding chicks; (7) Housing and yarding poultry. Special lines of investigation are taken up from time to time as necessity demands.

Bulletins are issued on these subjects, which, with the bulletins of other departments of the Station, may be obtained free of charge by addressing the Director, Experiment Station, Manhattan, Kan.

Other departments are:

AGRONOMY.
ANIMAL HUSBANDRY.
BACTERIOLOGY.
CHEMISTRY.
ENTOMOLOGY.
HORTICULTURE.
VETERINARY SCIENCE.

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THE MARKETING OF EGGS.

THE question of the *troubles,* which are ever present, concerning the handling and marketing of eggs, has been brought forcibly before this department during the past year. The College has been advocating to the poultrymen of Kansas the putting on the market of first-class eggs. Invariably the reply from the farmers was as follows: "Show us how we can make anything by this and we will do it." It is one of the duties of the Poultry Department to determine how to handle and market eggs properly and by so doing turn more cash into the pockets of the poultrymen.

STATISTICS.

Before the financial end of this subject can be discussed it would be advisable to look into the egg business of this state as shown by the government and state statistics. When our state is compared with others as regards the value of poultry and eggs, we stand about *fifth,* Iowa, Illinois, Ohio and Missouri coming ahead of us, but when we consider the value per capita the state of *Kansas leads* all other states by a large margin.

The federal statistics given in the twelfth census (1900) gave the number of eggs produced in Kansas in 1899 as 73,190,590 dozen, valued at $7,237,111. This does not include eggs consumed at home.

Hon. F. D. Coburn, in his sixteenth biennial report, gives the value of poultry and eggs of 1897 as 37 per cent of the value in 1907, and the value in 1887 as 17 per cent of the 1907 products. This shows a remarkable and steady increase in the product of the Kansas hen. The value of poultry and eggs has increased over $1,000,000 annually since 1903.

If we take the egg crop of this state in 1899 as 73,190,590 dozen, valued at $0.091 per dozen, and multiply it by 2, as the proportionate increase in the value of poultry and eggs more than shows, we get 146,381,180 dozen of eggs as the result. It seems safe to assume that the average farmer uses in his home, either for the table or for reproduction purposes, one egg out of every four laid. If this is so, then we must add to the above figures 36,595,295 dozen for home consumption. This gives an estimate of 182,796,475 dozen of eggs produced in Kansas in 1909. With these figures before us it is easy to see the vast importance of the egg industry in Kansas.

THE EGG BUSINESS.

Selling eggs is one of the handiest ways for the farmer to get a cash or trade return for his produce, during all parts of the year, and if he can increase the efficiency of the machinery which produces and handles these eggs he is putting into his pocket good hard cash. The question is, How can this be done?

If any person should go into the average hotel or restaurant in this state and call for a soft-boiled egg, providing of course that he knew an absolutely fresh egg, he would be somewhat in doubt as to the freshness of any of the eggs put before him. Such a thing as this gives rise to wonder as to the cause of it and suggests a possible remedy.

Almost every housewife who is compelled to buy eggs constantly clamors for some method which she may pursue in order to always get *fresh* eggs. There is no housewife who has not some time or other had the great displeasure of handling spoiled or rotten eggs. This almost constant occurrence, with the possible exception of the winter months, practically compels those who lecture and carry on experiment station work to plead with the farmers who produce the eggs to put onto the market better produce. It is firmly believed that care in the handling of anything with a view to improving its quality or appearance for the market will be a financial profit to the one who does the work.

STATE STATISTICS.

About the 15th of October, 1909, there were sent out to as many egg buyers as was possible, a letter asking them to coöperate with the Poultry Division of the Kansas State Agricultural College in a campaign for better eggs. With this letter were two pages of questions which they were asked to answer. Over seventy replies were received, and as a result there are tabulated below some of the questions with a compiled set of answers. A perusal of these will give an idea of the conditions in the state, the causes of them, and what the buyers are willing to do.

KANSAS STATE AGRICULTURAL COLLEGE,
DIVISION OF POULTRY HUSBANDRY.
EGG STATISTICS.

1. Give a rough estimate of the number of cases of eggs you bought between October, 1908, and October 1, 1909. *Over 900,000 cases, representing 74 buyers.*
2. Do you buy case count the year round? No, *40;* yes, *33.*
3. If not, when do you buy loss off? *General average seems to be during the hot weather of July, August and September, though some buy loss off from May until December.*
4. What difference do you make in price when buying loss off? *Varies from 1 to 5 cts.; average, 2 cts.*
5. How many cases do you buy during the hottest thirty days of the year? *100,000 cases, representing 58 buyers.*
6. What is the per cent of "rots" during that month? *Average from 10 to 20 per cent, extremes 5 to 75 per cent.*
7. When you candle your eggs after buying, either loss off or case count, what, in a rough way, is the number of eggs lost from each case during months of: October? *Av., 3 doz.* November? *Av., 2 doz.* December? *Av., ¾ doz.* January? *Av., ½ doz.* February? *Av., ½ doz.* March? *Av., ¾ doz.* April? *Av., 1 doz.* May? *Av., 1½ doz.* June? *Av., 2 doz.* July? *Av., 3 doz.* August? *Av., 4 to 6 doz.* September? *Av., 4 to 7 doz.*
8. Do you not figure, during the part of the year when you buy case count, that you will lose at least from one to three dozen? Yes, *57;* no, *7.* If not, how many do you figure on? *Av., at least 2 doz. for the year round.*
9. If those bad eggs could be eliminated, could you not quote higher case-count prices? Yes, *69;* no, *none.* If so, approximately how much increase in price could you afford to quote? *Varies from 1 to 5 cts.; average, 2 cts.*
10. Is not the average run of eggs which you buy only fair in quality? Yes, *68;* no, *3.*
11. What causes the large number of rotten eggs coming to you? Is it the holding for higher prices by the storekeeper? Yes, *none;* no, *none.* Or is it because the farmer does not give the eggs proper care? Yes, *37;* no, *none;* both, *33.*
12. Do you think that a rigid enforcement of the pure-food law relating to bad eggs would make the farmer or storekeeper more careful? Yes, *all;* no, *none.*
13. Could you afford to buy loss off the year round? Yes, *23;* no, *40.* Why? "Yes": *Justice to all; better grade of eggs; more money for the farmer.* "No": *Competition prevents; eggs are good enough in winter; farmers do not candle; have no market for seconds; different standards of candling; dissatisfied farmers; hot weather prevents; candling expensive.*
14. In case a farmer or community of farmers were instructed as to the kind of eggs which are best to sell, and would ship directly to you first-class eggs always, could you afford to put a premium upon them above the regular price? Yes, *63;* no, *5.* How much? *Varies from 1 to 5 cts.; average, 2 cts.*
15. If we work up the community will you pay a premium for first-class eggs? Yes, *53;* no, *2.* How much? *Varies from 1 to 4 cts.; average, 2 cts.*
16. When you candle eggs how do you grade them? *No. 1; No. 2, including cracks, small, dirty, washed, and some "held" eggs; rots.*

17. Would you like us to get out a circular of education for the farmer concerning the proper way to handle eggs for the market, and telling him how the buyer grades eggs, so that in case he ships subject to candling he will understand his losses? *Practically every buyer desires having this circular printed.*
18. If you wish this, will you please give us a few suggestions as to what you would think best to put in it? *Instruct farmers to be less intentionally careless; tell them how to candle; tell them not to wash eggs; tell them to keep all eggs not strictly fresh at home; have them market eggs often; show them the difference in price between good and bad eggs, that could be obtained; teach carefulness; keep nests clean; keep eggs in dry place; cover eggs when bringing them to town; dispose of the male birds at end of the breeding season; gather eggs often; instruct as to the grading of eggs; instruct the farmer as to the loss he takes when he trades eggs with the merchant; there should be a law compelling the grading of eggs; there should be an examination for candlers the same as there is for cream buyers; instruct as to the pure-food law.*
19. Will you give us your best support in a movement for better eggs? Yes, *all;* no, *none.*

From this one can easily see that there is a loss to the state each year that amounts to considerable. If we take it that 146,381,180 dozen of eggs were marketed last year, then with the average loss of two dozen rots per case we will find that 9,758,745 dozen of eggs were absolutely lost, partly on account of carelessness. This does not include those classed as seconds. There is not the least bit of doubt but that 50 per cent of the rotten eggs could be eliminated, and if this was done, taking eggs at 16 cents per dozen, which is a fair average price for 1909, there would be saved to the farmers of the state over $780,699. An entire elimination of bad eggs would add over one and one-half million dollars to the pockets of the farmers. Is it not therefore worth the trouble?

CAUSES OF BAD EGGS.

It has been shown above that the loss to the state each year is enormous and beyond all reasonable justification, and therefore the cause must be found before we can get any farther. A review of the correspondence carried on with the buyers places the blame always, at least in part, with the farmer, for the following two reasons: First, some few farmers deliberately take to market eggs which they know are not fresh, because they know that the merchant is compelled to take them or lose their trade. Second, and by far the greatest reason, is because of ignorance on the part of the farmer as to what and how to sell eggs.

Some of the trouble lies with the small merchant, who generally gives trade for eggs. A storekeeper, especially in a small town, makes his livelihood from the farmers' trade. The farmer brings in butter and eggs and wants all he can get for them. One merchant in the town offers $5.20 per crate in cash. His competitor offers $5.40 in trade. The one offering $5.40 in trade, therefore, gets all the business. Maybe he loses on the eggs when he pays $5.40, but if he does he makes on the sale of his goods. When the man who originally offered $5.20 per case has lost his trade he becomes desperate, and offers $5.50 per case, and takes anything so long as it has a shell around it. That causes the farmer who loves the cold cash to make an extra effort to supply him with all the eggs he can get, and all the weeds, orchards, barn lofts, etc., are forced to give up their sometimes rather ancient supply of eggs. This competition compels all the small egg buyers in that town to pay a big price for any egg. Some merchants even offer two cents per dozen more for those sold for trade than they do those sold for cash. The price of goods is raised to meet the deficiency in the profit from the eggs, and the farmer makes almost nothing by the competition.

These eggs, which sometimes are 50 per cent rotten, are shipped to larger buyers, who figure on a loss and quote prices accordingly. The small merchant seldom makes a thing on his eggs, and must therefore realize largely on his merchandise. An outsider certainly fails to see the benefit of this kind of business to the egg producer.

These merchants sometimes try to realize on their egg deals, and through ignorance ofttimes hold for higher prices. Thus, in October and November, there is a great loss from "held eggs."

Thus it is easily seen that the farmer and the small storekeeper are both to blame, and competition for eggs (any kind) keeps the market flooded with bad eggs.

A man who deliberately tries to sell eggs which he knows are not fresh deserves no consideration from the people or the law, but the one who sells eggs which are not of the best quality simply through ignorance of what is correct deserves some information as to the proper methods to use in handling eggs.

HOW TO OBTAIN EGGS.

Eggs are produced by fowls only after their bodies have been supplied with a maintenance ration. The production of an egg is the hen's only means of reproduction, and this she cannot do until she has enough food to first maintain life. So it must be remembered in feeding a hen for laying that she needs a great quantity of feed. Some hens lay large, some small, and more medium-sized eggs. A large egg is desirable on all markets, and if the farmer wishes his hens to be largely egg producers he should keep on the farm those breeds of fowls which will lay large eggs. Such breeds as the Plymouth Rock, Rhode Island Red, Wyandotte, and some Leghorns, are the most popular farmer's fowl for producing good marketable eggs.

There is ofttimes much objection to the Leghorn on account of the inclination to lay small eggs, and yet it is not the least bit of trouble to produce hens of this breed which will easily lay eggs that weigh 1½ pounds to the dozen. If the strain of Leghorns kept do not do this, it will do no good to cross them with some other breed and expect to improve the size of the egg or yield of the flock. One year may show improvement, but the following ones are questionable. So it will pay any poultryman who cares to produce the best market fowl or the best eggs to breed pure and for a purpose.

HOW TO HANDLE EGGS.

When the hens on the farm are producing enough eggs to warrant the farmer's taking them to town, arrangements should be made to handle all of them properly. A convenient and clean place should be provided wherein the hens can lay. They should be compelled to lay here in a clean nest. The natural tendency of a hen is to go off in the weeds and make her nest. This should never be tolerated, and any eggs found in such places should be marked and kept at home.

It makes no difference how many hens are kept, a house suitable for them should be erected in which they should be compelled to roost and lay. Then if the nests are placed where the hens will not roost on them they can be kept clean. Straw that is dry makes the best nesting material, and if the nest could have a bottom made of one-inch-mesh wire it would be self-cleaning. If not, the nesting material should be changed often.

If the weather is bad and the hens' feet become muddy, the eggs should be gathered at least twice daily. This will keep the eggs cleaner. If the weather is hot they should be collected at least twice each day, and oftener if the temperature is very high. This prevents eggs from commencing to decompose, or the germ, in case there is any, to start development. If eggs are laid in barns, sheds, etc., a careful search should be made often, in order to be sure that none are gathered when stale.

As soon as the breeding season is over, the male birds should be separated from the hens. A male bird is not necessary for the production of eggs, but is useful only to fertilize the egg, which will be laid in spite of his presence. A fertile egg will commence development, consequently deteriorate, more quickly than will a sterile egg. A fertile egg when fresh laid is supposed to be already started in its development, and if a hen is allowed to stay on it any length of time it will soon be in condition not to be classed as a fresh egg.

KEEPING THE EGGS.

When the *clean, fresh* eggs are gathered they should be put in a clean, *dry,* cool place until marketed. Even though the place is clean and cool, if it is not dry, molds, etc., will commence development and the eggs will soon spoil. If the eggs become damp and they happen to be in contact with any colored material they will immediately become stained. Good egg cases in a cool, *dry,* clean place, kept up off of the floor, make an excellent receptacle in which to keep eggs previous to marketing.

Before these eggs are set aside for market, they should be gone over by the farmer as he collects them, and all small, stained, dirty, doubtful, incubator and rotten eggs should be removed. Small and dirty eggs, if used immediately, are just as good as large clean ones, but they will not sell well on the market, and if sent in with good eggs will spoil the trade. Therefore, they should be kept and used at home. No eggs should be washed, for the packers claim they will not keep well. All eggs from stolen nests, whose freshness is doubtful, and all incubator eggs, should either be thrown away, boiled for the little chicks or used at home. They should never be sent to market. Rotten eggs need not be discussed. Any person who will send one to market deserves all the penalty possible from the *pure-food law.*

MARKETING THE EGGS.

When eggs have been properly gathered, handled and kept previous to taking to market, the question of the number of trips to town should be considered. In hot weather the eggs should be marketed two to three times per week, and oftener if possible. If that number of trips cannot be made, coöperate with a neighbor and have him alternate days in the trips which must be made.

In the fall and spring eggs should be marketed at least once a week. Many buyers have had trouble in October and November with eggs classed as "held eggs." These are common, because most farmers believe that after frost eggs will not rot so quickly, but nevertheless they do evaporate and the air cells in them show the candler that they are stale.

Therefore, the more often eggs are marketed the greater are the chances that they will be good. If the sun beats down hot on the wagon, place a cover of some kind over the cases in order to keep out the unnecessary heat.

WHAT THE GRADES ARE.

If a farmer takes to town often the best and freshest kind of good eggs, he should get more for them than a man who does n't. He clamors for a grading system, while the other man does not. But it makes no difference what eggs are taken in, when they get to the large shipper he will candle and grade them. If a large per cent run bad, he quotes accordingly, and the farmer is paid by the small dealer at so much per case with the per cent of bad eggs figured in.

There are two ways of buying eggs. One is by case count, where the eggs are simply counted regardless of quality, and the other is by loss off, where the eggs are candled and paid for according to quality. The last way seems to be the fairest to all parties concerned, unless possibly during the months of December, January and February. During those months it does not seem necessary. Though every buyer and seller agrees that buying loss off is the fairest way, many buyers cannot do so, because competition tempts a competitor to buy case count in order to get the trade. About two years ago this was tried by several buyers, but one by one they all dropped back into the case-count method, because they were afraid of losing their business, which is of course their means of livelihood. But one buyer says that during that period his customers received from 1½ to 2 cents more per dozen than when he bought case count.

The ideal way to grade eggs is as follows:

Extras: Weigh 28-26 ounces; naturally and absolutely clean, fresh and sound.
No. 1. Weigh 26-24 ounces; sound, fresh and reasonably clean.
No. 2. Shrunken or stale, washed, small, stained and dirty.
No. 3. Checks—cracked, but not leaking.
No. 4. Rots. Incubator and decomposed eggs.

The way eggs are now often graded by the large buyer is as follows:

No. 1. Sound, good size, fresh and reasonably clean eggs, any color.
No. 2. Shrunken, dirty, stained, washed and cracked eggs.
Rots. Total loss.

If this first system could be adopted, even if it was necessary to abolish the class called extras, the man with good eggs would have some incentive to handle them properly.

SCORING EGGS.

Below are two systems of scoring eggs, which might be used at institutes for competition with eggs. The first one was suggested by Mr. P. E. Crabtree, institute lecturer for the Kansas State Agricultural College, and the second is used by the students in poultry husbandry at Cornell University.

MR. CRABTREE'S SCORE CARD.

25 per cent	Size.	
25 per cent	Shape.	
25 per cent	Uniformity of	Size. Shape. Color.
25 per cent	Shell.	

NEW YORK STATE COLLEGE OF AGRICULTURE, AT CORNELL UNIVERSITY.

DEPARTMENT OF POULTRY HUSBANDRY.

DESCRIPTION OF SCORE CARD FOR EGGS.

Dozen eggs.

Disqualifications: Extremes in size and shape; rough, freckled, dirty, or cracked shells; double yolks; shrunken, cloudy, spotted, or loose contents. Entire dozen to be discarded when more than two show disqualifications. When two or less eggs show disqualifications, deduct for each egg disqualified 8 points from the final score of the dozen.

Grades.

(Indicate grades by X, XX, XXX, XXXX.)

XXXX, "Extras." Large and uniform in size and color, weighing 28-26 ounces per dozen. Quality perfect. Score, 95 per cent or better.

XXX, "Firsts." Good size and uniform in size and color, weighing 26-24 ounces, scoring 85 per cent or better.

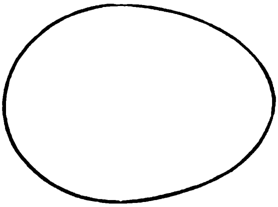
XX, "Seconds." Uniform in size and color and weighing 24-20 ounces, scoring 75 per cent or better.

X, "Thirds." Mixed in size and color and weighing 20 ounces, scoring 65 per cent or better.

Lower than 20 ounces—not worthy of a score.

Score Card.

Grade................

Scale of points—dozen eggs.	Perfect score.	Students' estimate.	Corrected.
Shape	10	......	......
Uniformly oval-like outline. Ideal: 			
Color	10	....	....
Rich dark brown for brown eggs, and clear, pure white for white eggs. Color should be uniform over entire shell, and throughout the dozen.			
Weight	20	....	....
For each ounce short of the class standard, cut ½ point.			
Condition of shell................	10	....	....
Spotlessly clean and unsmeared or glossy by washing.			
Quality	50	....	....
Fresh and sweet; clean, viscous white, rich golden yolk that stands up.			
Total	100		

CANDLING.

The grades above mentioned are mostly determined by candling. This is done by means of some good light, enclosed in a box or metal cylinder, in which are two small openings alongside of each other, to allow the light to pass through. The room in which this is kept is darkened, and the candler holds to the light in each hand an egg, large end upward, and gives them a quick turn, in order to view the entire contents as it whirls in the shell. To an expert this will quickly reveal the actual condition of the egg, and he will immediately grade and pack it accordingly.

To a novice candling is hard to understand, and great has been the trouble in the past when buyers have sent to the farmers the reports of their candling. If the loss is great he immediately accuses the buyer of crooked work, and the grading system is a failure. A farmer must fully realize that a large buyer is not going to figure to beat him out of a few eggs, for the chance he is running is too great and he could not afford the risk. He is an expert in the business, and knows more about what a marketable egg is than does the average seller.

An absolutely fresh egg, when held up before the egg candle, should be very clear and only the dim outline of the yolk be visible. There should be no air cell visible. Any egg other than that is not absolutely fresh. At the large end a clear space, called the air cell, becomes larger as the egg grows older, caused by the evaporation of the water content of the egg. If a dark spot is noticed it is either a rot or a developing germ. A red blood ring is caused by a dead germ. Whiter streaks in the shell show that it is cracked. Thus, eggs may be graded by candling into fresh, stale, cracked and rotten classes.

CAUSES OF LOSSES.

There are three big dead losses in eggs—losses from cracks, "held" eggs, and "rots." Cracks are usually caused by shipping, due to rough roads and handling. The railroads will not pay for the losses, unless the eggs are so badly cracked that they become leakers and thus show clear evidence of the railroad's guilt.

"Held" eggs are caused by the great desire of either farmer or small buyer to wait for an advance in price. This is especially so in the fall of the year when the price is apt to rise at any time.

The third loss, rotten eggs, is caused by various things. One big cause is the heat of the summer. One hour's direct rays of the sun will put an egg out of condition during some of Kansas' hot weather, such as there was in the fall of 1909. Another is by the hens stealing nests and the eggs not being gathered until they had spoiled. Third is by carelessness on the part of the farmer. He may gather his eggs from one to three times per week, then take them to the kitchen, put them behind the stove, because it is the most protected spot, until they are ready to be taken to town. Thus the eggs go through a process of heating and cooling, which will surely cause rotting.

ANALYSIS OF EGGS.

The value of an egg as food is well known, but it may be well to give at this time a compilation of the analysis of 469 eggs laid by 23 hens, of the Plymouth Rock, Rhode Island Red, Wyandotte and Leghorn breeds, which was done in the chemistry laboratory at the Kansas State Agricultural College, by Dr. J. T. Willard and assistant R. H. Shaw, and published in Bulletin No. 159, March, 1909.

	Wt. in ounces.	Per cent. white.	Per cent. yolk.	Per cent. water.
Egg	1.88	56.96	33.18	9.98

EGG.

	Per cent. protein.	Per cent. fat.	Per cent. water.
Egg	12.82	10.58	65.89
Yolk	17.75	32.27	40.58
White	12.29	....	87.63

THE PURE-FOOD LAW.

The foregoing subjects have been discussed with the idea of instructing the producer of eggs how he should care for and market his eggs and the results caused by negligence. There is always the old saying that "ignorance is bliss"; but it is also true that ignorance of law is no excuse for one accused of some wrong deed.

It is hoped that the aforementioned facts will serve to show the farmer and small buyer what the kinds of eggs are that should be marketed, and how to detect undesirable ones. But if any one who sells eggs does not care to do what is right in the egg business, then there is a law with which he may be punished.

This can be found under the Kansas food and drugs law, and rules and regulations, section 3:

"That the State Board of Health is authorized and directed to make and publish uniform rules and regulations, not in conflict with the laws of this state, for carrying out the provisions of this act . . .; and said Board of Health is further authorized and empowered to make, define, adopt and publish standards of quality, purity and strength for food and drugs. Any person who shall violate any of the rules and regulations so made and published in the official state paper shall be deemed guilty of a misdemeanor, and on conviction shall be punished by a *fine not exceeding fifty dollars or imprisonment in the county jail not more than six months, or both, in the discretion of the court.*"

"SEC. 7. . . .; *sixth,* if it consist in whole or in part of a filthy, decomposed, tainted or putrid animal or vegetable substance or any portion of an animal unfit for food, whether manufactured or not, or if it is the product of a diseased animal or one that had died otherwise than by slaughter."

"REGULATION 11. (*a*) The sale, keeping for sale or offering for sale of any food product that contains a poisonous or deleterious ingredient or substance due to filth, putrescence, disease or decomposition is prohibited.

(*b*) The sale, keeping for sale or offering for sale of undrawn poultry, game or fish is prohibited.

(*c*) *The sale, keeping for sale or offering for sale of tainted or rotten eggs is prohibited.*"

"REGULATION 31. The serving for food in any restaurant, hotel or dining-car in Kansas of any poultry, game or fish that has been refrigerated or kept in cold storage with the crop or entrails undrawn is prohibited."

During the past year the punishment of offenders of the above mentioned have been very few. Nevertheless the perpetrators of this act have been very numerous. It is known, however, that the selling of bad eggs is carried on mostly because of ignorance on the part of the seller. Now that a publication of the proper way to handle eggs has been made, there is no reason whatever why every person who sells a bad egg should not be punished to the limit.

Dr. S. J. Crumbine, secretary of the State Board of Health, has promised the writer that he will, sometime in the year 1910, take his entire corps of inspectors and make a campaign over the state for any who violate the pure-food law as regards eggs. This will certainly be done, and if possible pushed to the limit, so it behooves every one who handles eggs to be as careful as possible in the marketing of them. This is not a pleasant or desirable thing to do, but if necessity demands it prosecutions will be made.

REMEDIES.

The great loss to the state caused by the existence of rotten eggs and the ways of eliminating them have been discussed, and it is now evident that to the businesslike farmer there is a way whereby he may improve his egg business and yet make money by so doing.

It is hardly reasonable to expect any one to improve their business conditions unless they realize a financial benefit therefrom. Every one likes to produce the best of anything, but if they find that more cash can be made by selling an inferior grade of stuff it surely seems reasonable that they do so. But in this question of handling eggs an improvement means more profit and should therefore be done.

There are three ways whereby a poultryman may dispose of his marketable eggs. First, by selling to a buyer, who either ships without grading or candles and disposes of them according to their quality. By this method of selling, the producer is able to take advantage of the intense competition, which is generally ever present among local buyers. That raises the general run of prices, until some merchants will even complain that they are too high for them to realize any profit after the eggs have been candled.

If a farmer brings in good No. 1 eggs every week, he should get more for them than any one else. At the present time he does n't, and the tendency is to let the care of the eggs *slide*. The compiled data, shown on page 245, shows the number of buyers who say that they could afford to pay better prices for extra good eggs. It also shows how much they could afford to pay and the number who will pay it. Would this increase amount to much to the farmer? The average increase is 1½ or 2 cents per dozen. Let us figure that the average Kansas farmer's hen produces 100 eggs per year. If he has 200 hens, they will produce 20,000 eggs for him yearly. If one-fourth of this number are consumed at home, then 15,000 will be salable. A premium of 2 cents per dozen would mean 1250 × .02 = $25. Is it not worth the trouble financially, not considering the law, to take care of the eggs produced?

The question now comes up as to how to get the buyer to pay this premium. The storekeeper will not do it; and if he won't, then let him lose the trade and you ship to a near-by large buyer. They will be glad to get this trade and will treat you in the best possible way. At first they will quote market prices only, until they are satisfied that the quality is as represented, then they can be made to pay the desired premium.

One buyer told the writer of several customers who brought in superior, large, fresh eggs, but on account of the prevailing methods they received no more for them than any one else.

The question was then asked of him as follows: "If those customers would ask you for a premium for their eggs, would n't you pay a reasonable one, rather than lose their trade?" The quick reply was, "Yes, indeed." That is but one method whereby a farmer can make a buyer pay him for his efforts. But since the average farmer will not hustle trade, the buyer will of course not offer it. Egg buyers compete for eggs and they desire that they be good, so why cannot the producer compel him to pay for quality? All of this may not seem reasonable in all communities, and yet the writer has yet to see over a dozen poultrymen who hustle business for their egg trade. They seem content to take what is offered.

In the present day of the farmer, who at least desires to be businesslike with most of his farm work, there is no reason whatever why several in a community cannot ship eggs together in lots of fifteen dozen and upward, and work up a business that will be large enough to make a buyer want their trade. In Denmark the coöperative handling of eggs has been successful for years. In Quebec, Canada, it has been working successfully in several communities. In the Southern states there are also several coöperative egg localities.

In Kansas coöperative poultry associations could be easily managed with profit to all. Other coöperative organizations are successful, and why not those with poultry and its products?

In case an association of this kind is agitated, the following suggestions are made for its benefit: Secure a number who are interested enough to stick to the association, whether they lose a little at first or not, and organize them into an association, adopting a constitution, which shall give the name, object, membership, dues, officers and their duties, meetings and rules. Under the rules should be given the grades of eggs and of poultry and the proper way to handle, mark and market them. This can be made very successful in small communities, if only tried. If nothing is ventured nothing is gained.

The second way of marketing eggs is to sell at retail, or at a slight premium, to a hotel or restaurant where they will buy in quantities and yet pay well for good produce. One farmer who kept 300 White Leghorns told the writer that this method of supplying one good restaurant netted him a clear profit of over one dollar per hen each year.

The last method is to sell to private trade, by peddling around to small customers and selling at a premium. This way is not used in this state, but is a good one, nevertheless. To prove this, an example will be given. In the fall of 1908 the Poultry Division of the Kansas State Agricultural College endeavored to market nice, first-class eggs, all one color, in fancy cartons, and sell them at a premium. The idea was laughed at by many, and predictions were made as to its quick failure. For two months the situation looked unfavorable, but in a short time trade picked up and in one year these eggs were bargained for a week before they were laid, the buyers to call at the poultry house, and the price paid to be four or five cents above downtown retail prices. An example of how this worked may give the reason for its success. One customer called for a dozen eggs, but refused to take them when three cents premium was requested. In three days he came back, asking to have his name kept on the regular order sheet. He said that the eggs he bought in town contained too many bad ones to suit him. It has therefore been proved in a town such as Manhattan, where there is little demand for fancy trade of any kind, that there are always some people who will pay for quality.

The Poultry Division has a small and rather inefficient poultry plant, but its employees are always ready to help and visit any who are sufficiently interested to send a letter. The poultry industry of the state is so large and its reputation so great that there seems no plausible reason why it cannot be among the first in efficiency and quality.

The egg question and its relation to the farmer's pocketbook is but one phase of the poultry business. It is hoped, if the proper support is given, to work on others later. This pamphlet is written simply to appeal to the reason of the farmer with regard to the marketing of his eggs. The law is already made, and it is hoped will not need to be enforced in 1910.

NAMES AND ADDRESSES OF KANSAS EGG BUYERS WHO FILLED OUT BLANKS SENT TO THEM CONCERNING THE MARKETING OF EGGS.

Adams Mercantile Co., Chanute.
Anthony Poultry and Egg Co., Anthony.
Beatrice Creamery Co., Topeka.
S. M. Baker Produce Co., Caldwell.
W. W. Brown, Salina.
J. E. Brewer Co., Abilene.
Beatrice Creamery Co., Salina.
Barker Mercantile Co., Burns.
Karl Burns, Ellsworth.
Bucklin Produce Co., Bucklin.
Brungarat Produce Co., Victoria.
Farmers Produce Co., Burlington.
E. Buennings, Plainville.
A. Childs, Lindsborg.
J. C. Cooper, Lincoln.
H. A. Cowen, Hays.
S. M. Christian, Cassaday.
D. Corkins, Cimarron.
R. D. Carpenter & Co., Hartford.
H. C. Dryden, Harper.
Downs Produce Co., Downs.
J. D. Emery, Glen Elder.
Ellsworth Produce Co., Ellsworth.
Francisco & Egbert, Ingalls.
Fravel & Lewis, Kinsley.
Florence Creamery Co., Florence.
D. F. Fraker, Ellsworth.
B F. Aycuff, Garnett.
J. F. Grennan, Waverly.
Garnett Poultry and Produce Co., Garnett.
Grovier Produce Co., Great Bend.
Hill & McQuary, Hiawatha.
M. J. Hopper & Son, Cimarron.
Howard & Howard, Belleville.
Hoops & Frizzell Produce Co., Kinsley.
T. Jensen Brothers, McPherson.
T. Jensen & Bros., Emporia.
Kansas Ice and Storage Co., Salina.
A. S. Kininmonth, Winfield.
Kansas Egg and Poultry Co., Hillsboro.
Louis Kesler & Son, Hiawatha.
Latham & Son, Ottawa.
Little River Produce Co., Little River.
H. R. Morris, Mapleton.
J. L. Martin, Watonia.
Metz Bros., Concordia.
Morris Produce Co., Russell.
Marion Produce Co., Marion.
National Poultry and Egg Co., Atchison.
John Nemechek, Ellsworth.
Alec Ogle, Smith Center.
O'Connor & Stratton, Hartford.
L. L. Place, Cedar Point.
Palmer Bros., Pittsburg.
Seymour Packing Co., Topeka.
Perry Bros., Manhattan.
A. E. Patterson, Wellsville.
Paden & Thompson, Lyons.
J. H. Reid, Lebo.
W. J. Riggs, Pawnee Rock.
Rothe Mercantile Co., Otis.
Springer Produce Co., Geneseo.
Salina Poultry Co., Salina.
Swift & Co., Hutchinson.
Jno. Stuart, Concordia.
Scheuerman & Son, Otis.
Sylvan Grove Produce Co., Sylvan Grove.
H. C. Schlegel, Otis.
Tampier & Knakal, Wilson.
E. L. Thomas, Nortonville.
Wells Bros. Produce Co., Coffeyville.
W. S. Young, Larned.

THE FOLLOWING BULLETINS
ARE AVAILABLE FOR DISTRIBUTION.

No. 12....Preliminary Experiments with Fungicides for **Stinking Smut** of Wheat.
No. 13....Experiments with Oats.
No. 15....Additional Experiments and Observations on Oat Smut.
No. 16....Experiments with Sorghum and with Sugar Beets.
No. 43....Experiments with Sorghum and Sugar Beets.
No. 52....Kansas Weeds—Preliminary Circular on Distribution.
No. 120....Tests of Forest Trees.
No. 121....Treatment and Utilization of Flood-damaged Lands.
No. 129....Kansas Mammals in their Relation to Agriculture.
No. 136....Press Bulletins Nos. 125-151.
No. 137....Variations in the Test of Separator Cream.
No. 138....Effect of Bacteria in Wash-water of Butter.
No. 139....The Study of Corn.
No. 140....Milking Machines.
No. 141....Commercial Seeds of Brome-grass and of English **and Kentucky** Blue-grasses: Adulterants and **Substitutes and** their Detection.
No. 142....The Value of Oil in Road Improvement.
No. 143....Disposal of Dairy and Farm Sewage, and Water Supply.
No. 144....Small-grain Crops.
No. 145....Spraying.
No. 148....Law Regulating the Sale of Commercial Fertilizers.
No. 149....Prevention of Sorghum and Kafir-corn Smut.
No. 150....The Hen's Place on the Farm.
No. 153....Deterioration of Red Texas Oats in Kansas.
No. 154....The Mound-building Prairie Ant.
No. 155....Alfalfa.
No. 158....Analyses of Registered Feeding-stuffs.
No. 160....Cow-peas.
No. 161....The Influence of Depth of Cultivation upon Soil **Bacteria and** their Activities.

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Kansas State Agricultural College.

EXPERIMENT STATION.—Bulletin 163.

ED. H. WEBSTER, *Director*.

FARM BULLETIN.

Veterinary Department.

DR. F. S. SCHOENLEBER, *Veterinarian in Charge*.

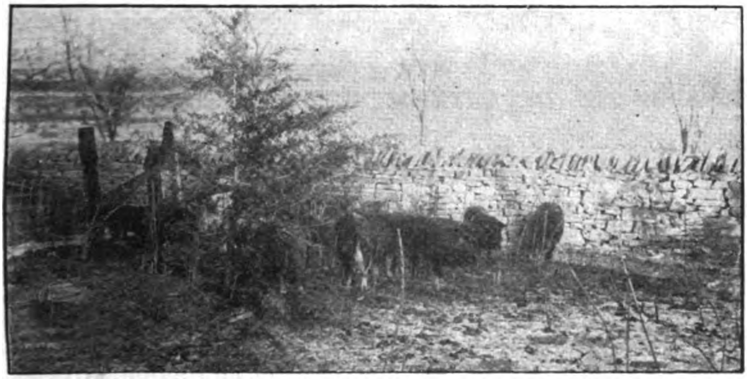

FIG. II.

Hog Cholera and Vaccination.

BY

DR. F. S. SCHOENLEBER.

MANHATTAN, KAN.
JANUARY, 1910.

DEPARTMENT OF VETERINARY SCIENCE.

Dr. F. S. SCHOENLEBER	Veterinarian in Charge and State Veterinarian.
Dr. K. W. STOUDER	Assistant Professor, in Charge of Surgery and Clinic.
Dr. L. W. GOSS	Assistant Professor and Pathologist.
Dr. BURTON R. ROGERS	Instructor and Anatomist.
Dr. J. H. BURT	Assistant and Physiologist.
Dr. F. M. HAYES	Assistant in Hog Cholera Serum Production.
Dr. E. F. KUBIN	Assistant in Hog Cholera Serum Production.
THOS. P. HASLAM, M. S	Assistant in Corn Mold Investigations.

WORK OF THE DEPARTMENT OF VETERINARY SCIENCE.

School of Veterinary Medicine:

Giving a full four-year course of instruction and graduating students with the degree of Doctor of Veterinary Medicine.

Investigating corn mold and troubles caused by diseased corn and stalks.

Production of anti-hog-cholera serum.

Production of blackleg vaccine.

State veterinary work of investigating contagious diseases.

Veterinary work connected with the State Live-stock Registry Board.

Supervision of testing cattle for tuberculosis.

Special lines of investigation are taken up from time to time, as necessity demands.

Bulletins are issued on these subjects, which, with the bulletins of other departments of the Station, may be obtained free of charge by residents of the state, by addressing the Director, Experiment Station, Manhattan, Kan.

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HOG CHOLERA AND VACCINATION.

In many sections of the state of Kansas hogs would be the most profitable of all crops if it were not for the ravages of hog cholera. The value of this crop would be increased several hundred thousand dollars per year in the state if the cholera could be kept in check, and the Kansas State Agricultural College has undertaken this task through the production and distribution of anti-hog-cholera serum. During the year 1910 the college expects to produce upwards of 2,000,000 cc. (cubic centimeters) of the serum, or over 100,000 doses. A considerable of this serum has already been produced and thoroughly tested both at the college and in private herds. These results warrant the above statements. The first serum that was produced at the college was tested by the veterinarians with a representative of the United States Department of Agriculture. It was done as follows:

Six susceptible shotes (pigs which would take the cholera very easily) were used, each weighing about forty pounds. They were each given two cubic centimeters of virulent blood, injected into the muscles of the thigh. (Virulent blood is blood filled with the germs of hog cholera and is taken from a hog almost ready to die with the disease.) Two of these pigs were each given in addition to this blood a full dose (20 cc.) of the anti-hog-cholera serum.

Two more were given only three-quarters of the regular dose of serum (15 cc.). These pigs were all of about the same age, size and condition, and were all kept in the same pen, fed and cared for alike.

The results were as follows: The two which received the virulent blood only promptly died with acute hog cholera as shown upon *post-mortem* examination. The one died on the sixth day and the other on the seventh day after the injections were made. The remaining four, the ones which received a dose of the serum in addition to the virulent blood never lost a feed and have remained well and hearty since.

This showed that when the serum was given in only three-quarters of a full dose it protected the pig against the cholera, showing that the serum was highly potent.

Before any serum produced at the Kansas State Agricultural College is sent out or used, it must be tested in the same way; it must prove, as the first did, that it will prevent the vaccinated hog from taking the cholera—it must prove potent.

Fig. I. Some of the buildings used in the production of anti-hog cholera serum at the Kansas State Agricultural College.

NATURAL IMMUNITY AND SUSCEPTIBILITY. During an outbreak of hog cholera there are usually a few hogs in the herd which do not show any signs of being sick. We say these hogs are naturally immune—that is, they either have only a very slight attack of the disease or they do not take the disease at all. After a hog has recovered from an attack of the cholera, it is also immune and will not take the disease the second time. Some of the herd take the disease and die in a few days; these we say are more susceptible—that is, they take it much more readily. A strong, healthy hog is considerably less susceptible than one which has been neglected in the way of feed or care. One peculiarity, however, is that quite fat and pampered hogs seem more susceptible than those in ordinary feeding or growing condition. In either case the vitality has been reduced.

ARTIFICIAL IMMUNITY AND VACCINATION. A hog can be made immune by vaccinating with anti-hog-cholera serum, so he will not take the disease. This is called artificial immunity and may last for a few weeks only, or during the life of the animal, according to the method used in vaccination. A very young pig, however, may outgrow this artificial immunity and require to be revaccinated, on the same principle as the human being is revaccinated against smallpox at variable periods of time.

Figure 1 shows a number of the buildings used at the Agricultural College for the production of the serum. The larger building is used for the laboratories, the medium-sized one for a bleeding-house (8 by 10 ft.), and the smaller ones for the pigs which furnish the virulent blood. The small houses are stood over a water-tight trough, which is filled with antiseptic solution so that all of the germs in the seepage from the pens are caught in this trough and killed in this solution. (These houses are 4 by 6 feet, and usually contain four diseased pigs.) After each lot of pigs are removed the houses are thoroughly disinfected and all straw and litter burned to prevent the spread of the disease.

Figures III and IV show the inside of the laboratories and figure VII shows the inside of the bleeding-house where the blood is drawn which furnishes the serum. This process requires great care and cleanliness. The hog is first covered with a sterile cloth to prevent any dirt or germs from dropping into the vessel which collects the blood as it is drawn from the animal. The tail is shaved closely, then thoroughly sterilized with a strong antiseptic solution before each bleeding. The blood is immediately taken to the laboratory and defibrinated, leaving only the fluid part of the blood, which we call the serum. To this serum is added a small amount of a weak solution of carbolic acid to partially preserve it. It is then stored in a cool place until tested on some pigs, when, if it proves potent, it is ready for use.

HOW SERUM IS PRODUCED. Before the hog is ready to be bled for this serum it must first undergo the process of hyperimmunization—that is, his blood must be brought into a condition so that when it is drawn and injected into other hogs it will prevent them from taking the cholera. For this process one is taken which is immune to cholera—that is, it has either recovered from a case of cholera or has been vaccinated against the disease, and will therefore not take the disease again. Into this animal is injected, through the veins of the ear usually, five cubic centimeters of virulent blood for each pound of weight of the hog; for instance, a 200-pound hog receives

1000 cc. of virulent blood. After ten days the hog is ready to produce blood for serum and is bled usually three times more at intervals of seven days, and if the tail holds out he is then rehyperimmunized and again bled two or three times, the same as before. In either case at the last bleeding the hog is killed and all of his blood taken. The serum from all of these drawings is mixed together and its potency tested. If it is potent, it is ready for use. This is necessary as the serum from the last drawing is usually less potent than that from the first drawings, and after it is all mixed together it should be a serum of average potency.

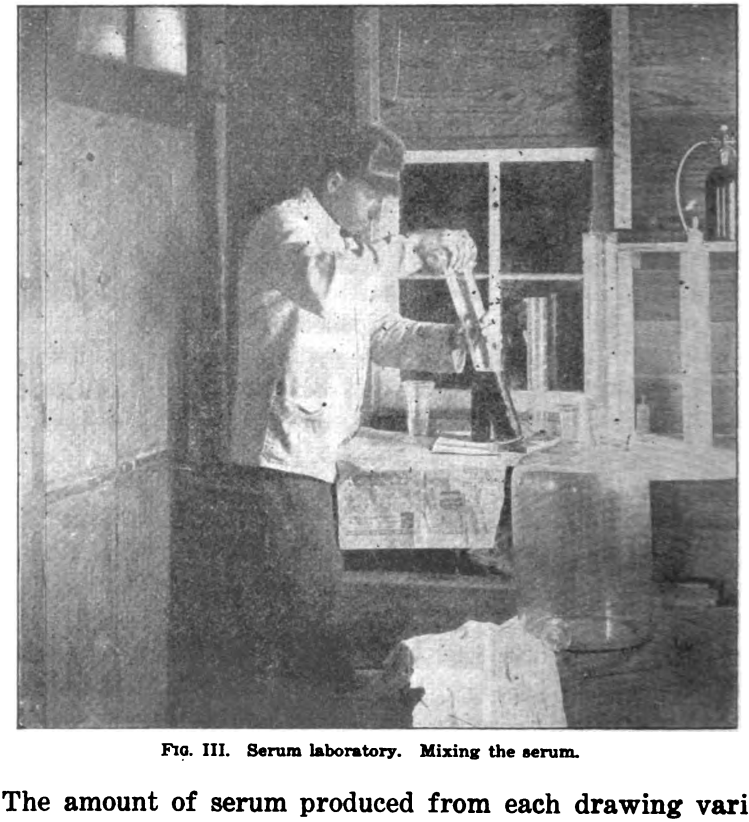

FIG. III. Serum laboratory. Mixing the serum.

The amount of serum produced from each drawing varies with the size of the hog, with his condition, the character of the weather and the manner in which the animal has been fed and cared for. A 200-pound hog will produce usually 600 cc. of serum at each bleeding, or a total of 3000 cc.—the last bleeding when killed usually yields 1200 cc. of serum.

It takes much practice and patience to inject such a large quantity of blood into the ear vein and also to draw such a large quantity from the tail of the hog. All of these operations must be done with thoroughly antiseptic precautions, to produce potent serum and to prevent injury to the pig itself or accidents to the serum.

To produce virulent blood enough to hyperimmunize a 200-pound hog requires three or four pigs weighing about forty pounds. They must be given a severe form of the disease and must be ready to kill at, or near, a certain time, as the virulent blood must be used for this work within a few hours after drawing. Again, in testing the serum it is necessary to use several more pigs. These are not all a total loss as it is usually possible to save their blood by killing them when they are about to die with the disease. Here again is the knowledge of the expert required. If the pig is killed too soon, the blood is not virulent enough for use, and if allowed to go too long before killing, the pig is liable to die and the blood cannot then be used at all. In order to produce this 3000 cc. of serum it requires one 200-pound hog and about five smaller pigs. This amount of serum will vaccinate about 150 hogs, so that for every 6 pigs sacrificed the lives of 150 are saved, or one pig for 25 (4 per cent).

EXPERTS NECESSARY TO PRODUCE THIS SERUM. Two expert graduate veterinarians with several high-grade helpers are now devoting their whole time to the production of this serum under the direction of the head of the veterinary department. This high-grade help is necessary; it reduces the danger of producing poor serum and also reduces the cost to a minimum as poor serum cannot be used at all.

COST OF THE SERUM AND SIZE OF THE DOSE. After the serum has been tested and found to be potent, it is put up in bottles of three sizes, sealed, and stored in a cement cellar where it can be kept at an even temperature until sent out for use. The small-sized bottle holds 100 cc., or enough serum to vaccinate five shotes weighing from 30 up to 100 pounds. The dose for this size animal is 20 cc. The larger bottles hold 500 cc. and 1000 cc. respectively, or 25 and 50 ordinary doses.

A pig weighing less than 30 pounds requires only from 10 to 15 cc. of serum. The large hog requires an increased dose, depending somewhat upon his weight and condition. Ordinarily a hog weighing 500 pounds would require at least 60 cc., and the pampered and very fat hog a larger proportionate dose.

At the present time the cost of the serum approximates somewhere in the neighborhood of one and one-half cents per cubic centimeter, at which price it is sold, making the cost per dose for the shote of 100 pounds or less 30 cents for the serum only. As the college has no funds for the production of the serum, it will be necessary to make a charge for it, at least until after the meeting of the next legislature.

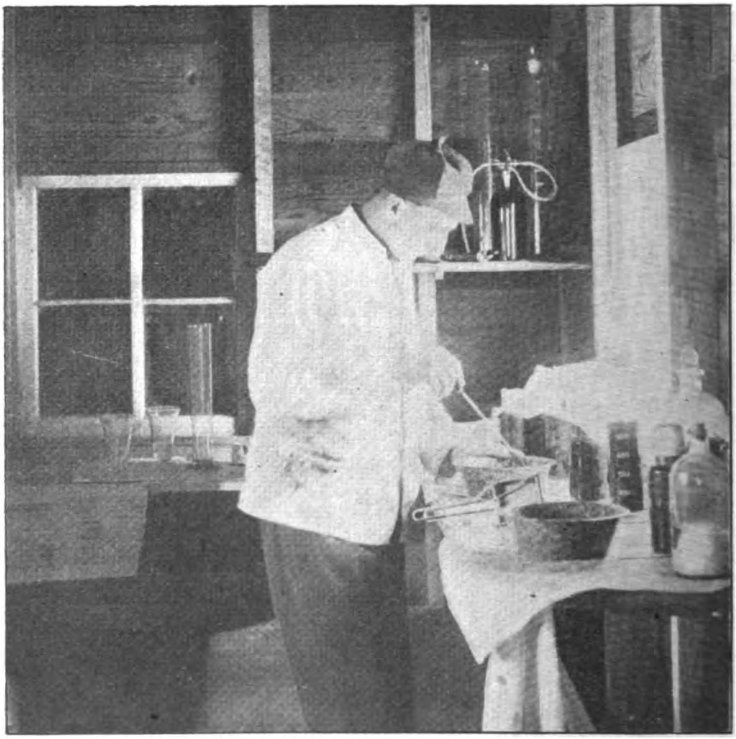

FIG. IV. Defibrinating the virulent blood. Serum laboratory.

Only the actual cost of the production will be charged, however. At this time we have not had enough experience in its manufacture to gauge accurately the cost, and the price fixed above is based on the best information we have in our own experience and on the experience of other states. Michigan charges its farmers two cents per cc., or 40 cents per average dose. Minnesota charges about the same. The Iowa legislature appropriated $8000 for the manufacture of this serum and they are charging their farmers "about 50 cents for a dose sufficient to inoculate a hog weighing 150 pounds." Ohio has three qualified veterinarians upon this work and they are selling the serum at 25 cents for an average dose.

Every economy will be practiced that is consistent with the production of serum of high protective powers and free from any foreign infection. It is hoped that it will be found possible to produce this serum at a lower cost than thirty cents for an average dose. In any case the price will be determined by the cost of production, and in no case will any profit be charged.

VACCINATING HOGS. Anti-hog-cholera serum will not cure hog cholera any more than vaccinating will cure a human being who is sick with smallpox. It is true that vaccinating may reduce the severity of the case when done in the beginning of the disease, or at the time of first exposure, but it is not expected to cure the disease. The same is true in vaccinating a hog. The serum will not cure the disease, *but it will prevent it.*

TWO METHODS OF VACCINATING. The first method is to use the serum alone. In this method there is simply injected into the muscles of the hog a dose of the anti-hog-cholera serum, which makes the hog immune against cholera for a time varying from a few weeks to several months. This is the method used when, for instance, a very fat show herd is vaccinated. It is absolutely safe.

It is also used in herds where the cholera already exists and some of the animals have been exposed only a few days. After the disease has been in a herd for three or four days, vaccinating seldom does any good. Thus the earlier the vaccination in these cases the more certain the results. A day's time here may mean either the losing or saving a large part of the herd.

Where vaccinating is done in diseased herds, the amount is increased from one-half to double the regular sized dose. The second method is one in which there is some danger, but the results, if the animal survives, renders it immune for the rest of its life. It is the so-called serum simultaneous method, in which there is injected at the same time, in addition to the serum, a small amount of virulent blood or blood taken from a hog very sick with the cholera. This method really gives the hog a very slight form of the disease and as a consequence the animal does not take the cholera the second time—it has been artificially immunized. This is the most satisfactory method and is used in a healthy herd, that is, before they become infected. Great care is here necessary that too much of the virulent blood is not used; if the dose of this is too large, the form of the disease may become so severe as to make the hog quite sick with the cholera or even cause death.

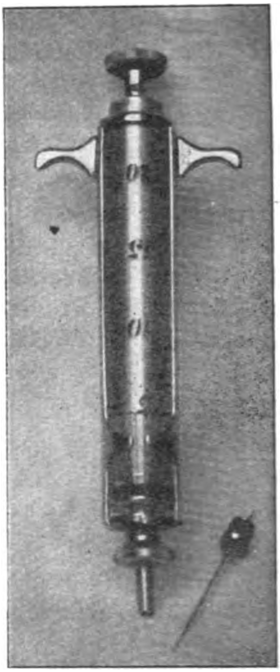

FIG. V. Hypodermic syringe, holding 20 cc., used in hyperimmunizing and vaccinating hogs.

VETERINARIANS WILL DO THE VACCINATING. On account of using the dangerous virulent blood and the ease with which these germs are spread, it has seemed advisable to have the vaccinating done, for a time at least, by graduate veterinarians, who have received proper instructions in the methods and are qualified to handle the dangerous materials. This will reduce the danger to a minimum, as in spite of the greatest care, there are at times losses from vaccinating.

AGE TO VACCINATE AND SIZE OF DOSE. The shote weighing from 30 to 100 pounds is taken as the standard size and the dose is 20 cc. of serum and 2 cc. of virulent, or infected, blood. In larger, fat or pampered hogs the dose is one-half more to double this amount, the maximum dose being 60 cc. Suckling pigs a quarter to a half less. It is always to be remembered that the younger the pigs are, the more probability there is of their outgrowing the immunity. Suckling pigs are liable to become susceptible again in the course of several months. Hogs in infected herds also receive about one-half more or a double dose, and if it helps them, they should be revaccinated in from four to six days.

IMMEDIATE EFFECTS OF VACCINATION. When the serum is potent and the work properly done the hog seldom loses a feed. The serum, however, causes a reaction and slight fever in the animal and for several days the temperature may vary several degrees, sometimes going to 106 degrees and even higher. From six to ten days after vaccinating the temperature should be back to normal again—about 103 degrees.

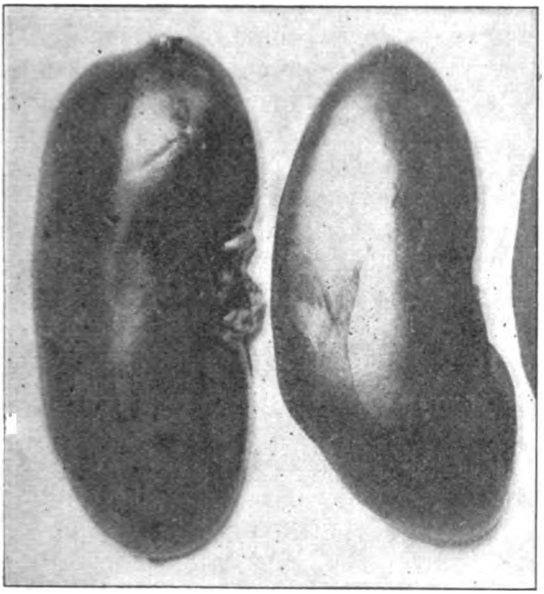

FIG. VI. Diseased kidney, showing the spotted appearance frequently found upon post mortem in hogs which have died with the cholera.

LOSSES FROM VACCINATION. The susceptibility of hogs to the disease varies greatly in different herds and even in the same herd. This was mentioned when describing the different degrees of immunity, the one condition really being the opposite of the other. At times there are a few hogs in a herd which are so susceptible to the cholera germ that no amount of serum will prevent them from dying with the disease. Again there is some danger of losses in vaccinating hogs, not alone from the fact that they might be extremely susceptible (hypersusceptible), but from the infection through the wound made by the needle. This loss all told, when the work is properly done, should not be more than from one to two per cent of the animals vaccinated in healthy herds, and frequently there are no losses whatever.

CARE OF HOGS BEFORE VACCINATING. All that is necessary before vaccinating is to cut down the rations two or three days before, feeding very little corn. Keep the animals clean and in dry and comfortable quarters, and if possible in disinfected pens. If the weather is favorable, a dipping would be all right a few days before vaccinating.

TREATMENT AFTER VACCINATING. From the fact that there is always more or less fever caused by vaccinating and more or less danger of the animal becoming infected through the wound made by the needle of the syringe, the following after-treatment would suggest itself: Spare diet for three or four days, especially of corn, but plenty of water, thoroughly clean and comfortable pens with plenty of clean bedding, with absolutely no chance to get into mud of any kind. The more mud and dirt the more danger. They should not be dipped or operated upon for at least two weeks after vaccinating.

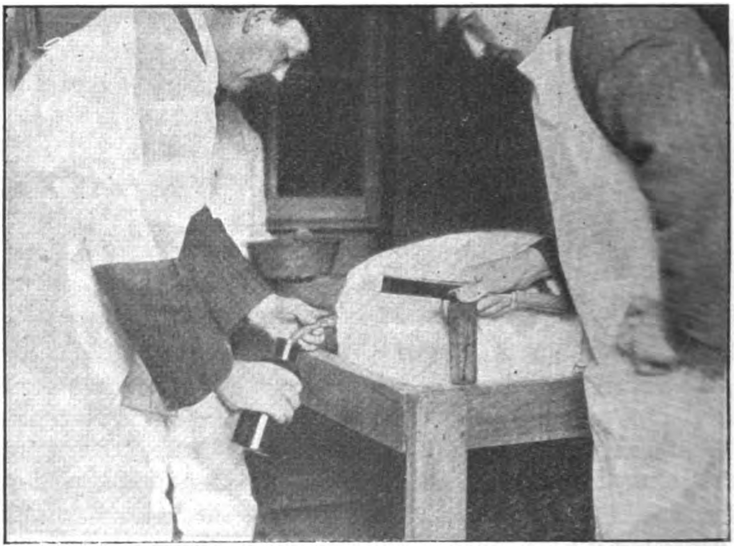

FIG. VII. Method of drawing blood from an hyperimmunized hog. The animal is covered with a clean piece of muslin to prevent dirt from falling into the vessel with the blood.

VACCINATING INSTRUMENTS. Two hypodermic syringes are used in vaccinating. One for the serum which holds 20 cc., and one for the virulent blood holding 5 cc. The two sizes are used to prevent any mistakes being made. A thermometer is used for taking the temperatures, as we make it a rule not to use virulent blood if the temperature is high, using only the serum.

Strong antiseptics are also used to disinfect the point of injection, especially where the virulent blood is injected. If this is not done the small particles of a drop or so on the end of the needle may infect the whole premises. This is very important.

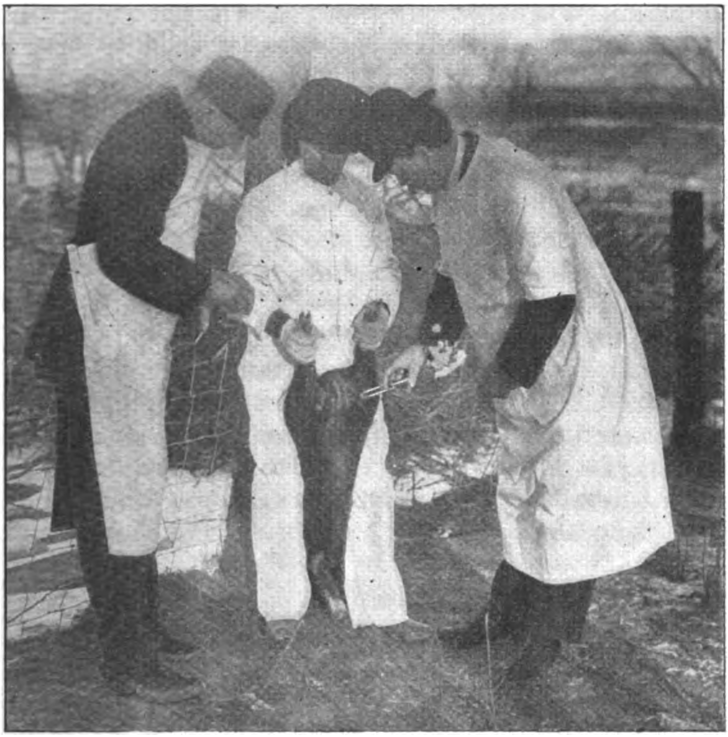

Fig. VIII. An easy way of vaccinating a light shote.

HOLDING THE HOGS WHILE VACCINATING. The pig up to the 100-pound shote is easiest handled by an attendant holding it up by the hind legs, belly forward and head held between the attendant's legs, as shown in the illustration, figure VIII. Very heavy hogs may be caught by placing a rope around the front leg or snout and held around a tree or post, or may be run into a chute or crate and vaccinated as in figure X.

FORMS OF THE DISEASE. Hog cholera is very contagious, but affects swine only, and shows itself in one of two forms, either acute or chronic. It is caused by a germ in the blood and tissues of the hog, and up to the present time has been grown nowhere else. In favorable locations it seems to live for many months. The acute form usually kills in from six to sixteen days. The chronic form is more mild and runs a slower course, the hog continuing sick for a month or more before death or recovery takes place.

CONDITIONS FAVORING THE DISEASE. Overcrowding during cold weather in the sleeping quarters, especially where different sized animals are kept in the same pen. The smaller pigs become too hot, and then very easily catch cold. Damp, filthy, dark pens where little fresh air or sunshine can reach. Sleeping in a draft under buildings or windows; a pig requires twice the breathing space for every hundred pounds of his weight that is needed by either the horse or cow. Too much green corn. Too close or inbreeding.

The accumulation of vermin on the animal itself or in the pens. Too exclusive a corn diet. The hog being frequently a scavenger, following the cattle in all kinds of mud, filth and dust, is liable to breathe the germs or irritating dust and the lungs become infected with tuberculosis or other debilitating disease germs. In fact anything that has a tendency to weaken the system of the animal renders him a more fit subject for hog cholera.

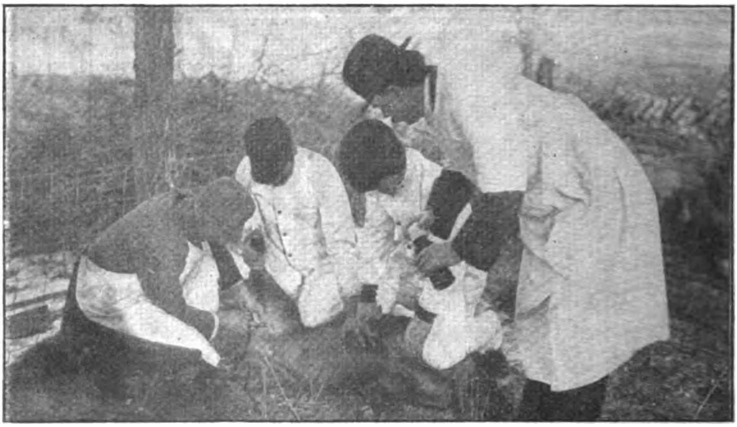

FIG. IX. Vaccinating heavy hogs.

AGE. While the disease has no respect for the age, size or breed of hogs when it once starts in a herd, it is usual for an outbreak to begin with the younger pigs and later to attack the more mature animals. But this is not always true.

SYMPTOMS. It usually starts with a diarrhœa. The pigs quit feeding, many have a cough and are dumpish for several days, lose all energy, gradually become weaker and die. The older hogs act in the same way, except that they do not usually become so thin before they die. Sometimes a constipation precedes the diarrhœa for a longer or shorter period. The discharges are usually very offensive. There is frequently a discharge from the eyes which resembles pus, which may be sticky enough to gum the lids together.

In many outbreaks one or two hogs may not feel well for several days, and before the owner is aware of the fact the whole herd may be infected and a greater or less number die every day. Some may show symptoms of a severe illness, such as fever, weakness, less of appetite, diarrhœa, redness of the skin of the abdomen or flanks and in patches around the snout or ears while others may show but a few of these symptoms before death.

CONDITIONS OR DISEASES WHICH RESEMBLE CHOLERA. Some conditions or diseases which resemble cholera are tuberculosis, although this disease is usually much slower in its progress; ordinary digestive troubles, due to improper feeding or unsanitary surroundings; anthrax; pneumonia, caused by dust, cold or worms. Garbage which contains much soap, lye or salt will frequently cause death with symptoms resembling cholera. Moldy bread, cottonseed meal, new corn, or too sudden changes of feed. Many things which are unfit for human food are thrown into the swill barrel, to form toxins and ptomains. These may cause vomiting, bloody diarrhœa, griping, nervous troubles, weakness, staggering gait, dullness, and death, all of which are laid to cholera.

SEASON OF THE YEAR. Hog cholera is most prevalent in the fall of the year and early winter. During the cold weather the cases, as a rule, become more chronic, do not die so suddenly, and a greater per cent of them get well.

MANNER OF INFECTION. This being a contagious disease, it follows that the germ of cholera must be carried into a herd before they can contract the disease. It is distributed somewhat on the same plan as are those of typhoid fever, scarlet fever or diphtheria in the human race. The germs are present in the blood and tissue of the affected animals, and are thrown off through every avenue of the body, especially through the urine and feces. In this way they infect the whole yard in which the hogs are kept, and also everything in the yard and pens. The smallest particle of dirt—so small that it cannot be seen, will carry enough germs to infect several herds of hogs. It is thus apparent that a stranger should not be allowed near the pens of sick hogs; neither should the attendant be allowed to leave the vicinity of the pens without first thoroughly cleaning and disinfecting his shoes or putting on others not infected. Dogs, cats, rats, crows and other birds—in fact, every living thing—should so far as possible be kept away from the infected places.

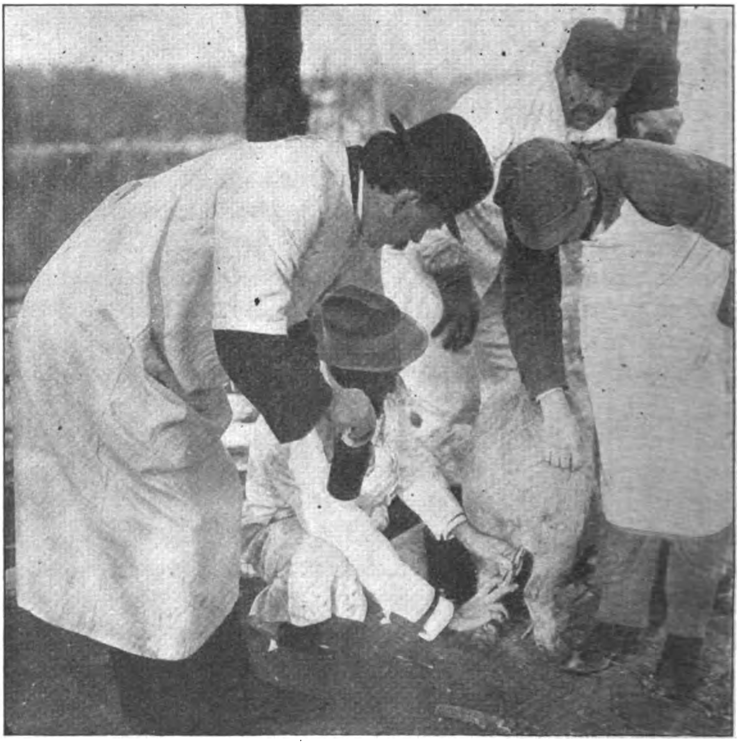

FIG. X. Heavy hog snubbed up close to a post and held for vaccinating.

Several years ago the writer had occasion to observe a number of outbreaks of cholera in different parts of the state, and found that the number of infected herds and losses along a stream of water were in some instances over fifty per cent greater than were found in herds two miles back from the stream. In several of these places hogs were found aboveground that had been dead from the cholera for four or five days and the rains washing the germs down the stream constantly.

PUBLIC STOCKYARDS. It seems that we must consider all public stockyards infected with cholera. Persons walking from these public yards to the depot platforms naturally infect these places. It is in this way that a crated breeding hog, for instance, shipped by freight or express, becomes exposed to the disease and may infect the whole premises when released from the crate. It is therefore not safe to take a hog upon the public highway even, especially if there has been cholera anywhere in the vicinity. In the fall of the year, during severe dust storms, the germs may be blown a considerable distance with infected straw, weeds, etc.

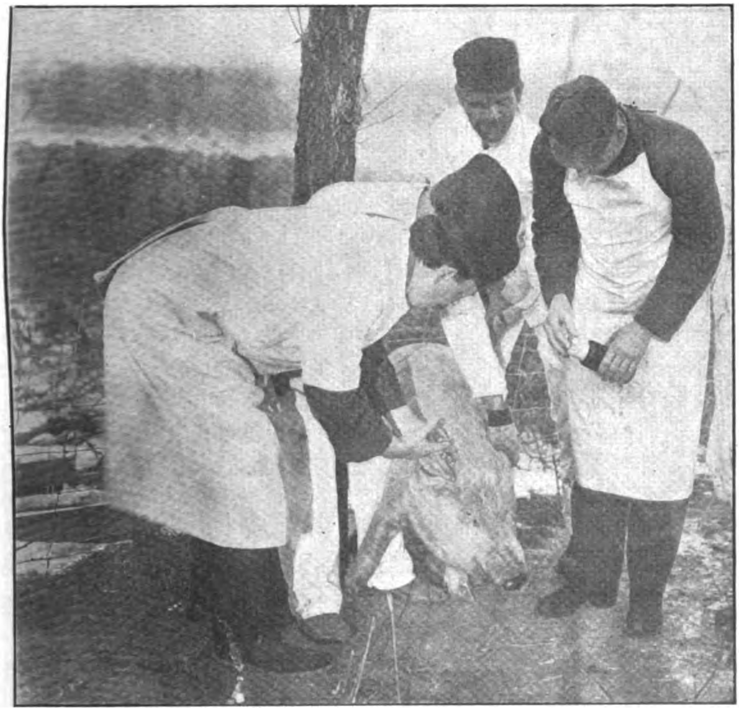

FIG. XI. Method of vaccinating a sow heavy in pig.

PERIOD OF INCUBATION. The time required for a hog to become sick with cholera after being exposed to the disease varies usually from six to fourteen days, but sometimes runs much longer.

PREVENTION OF THE DISEASE. When we recall the conditions which favor the disease and the manner in which the infection takes place, it will be seen that the feeding and care of hogs have much to do with the prevention of the cholera. Clean, dry pens, regular and proper feeding, comfortable sleeping quarters, plenty of sunshine, the pens cleaned and disinfected regularly, the hogs themselves dipped every few weeks when the weather is fit, all help in keeping up their vitality, and in this way warding off troubles of all kinds. Many hog raisers feed at regular intervals some of the following mixture to aid digestion and circulation and to prevent worms, especially where the animals are confined to a small lot:

Wood charcoal, powdered	1 lb.
Sulphur	1 "
Sodium chloride	2 "
Sodium bicarbonate	2 "
Sodium sulphate	2 "
Sodium hyposulphite	1 "
Antimony sulphide (black antimony)	1 "

This is the formula as published by the Bureau of Animal Industry some years ago. The dose of this mixture is one large tablespoonful to each 200 pounds of hog once per day.

After shipping a hog it should be dipped as soon as removed from the crate and kept away from all others for several weeks, and then dipped again before being allowed to come in contact with the rest. If a hog shows signs of sickness it should be at once removed and kept by itself until well.

In September, 1909, a breeder of high-class hogs, living several miles from the college, noticed three head sick, one almost dead. A *post-mortem* was held by members of the Veterinary Department of the college and the disease diagnosed as acute cholera. The remaining hogs were thoroughly dipped and removed to new, clean quarters and everything disinfected, and no further cases developed. Prompt, vigorous methods in this case saved the herd.

DISINFECTION. All straw, cobs and litter should be removed and, if cholera is present, burned, and a strong solution of some good coal-tar dip or crude carbolic acid, about one part of the dip to twenty of water, used on all woodwork and floor of the pens; slaked lime scattered over the ground and floors of the pens every few days will help to keep them clean.

POST-MORTEMS. Care should be taken to prevent blood poisoning of the operator as a result of the *post-mortem* of any animal. If a person has any sore on his hand he should not touch a dead animal, or if he should receive a cut or scratch during the examination the hand should be placed in pure kerosene at once, the sore well filled and the bandage saturated with it.

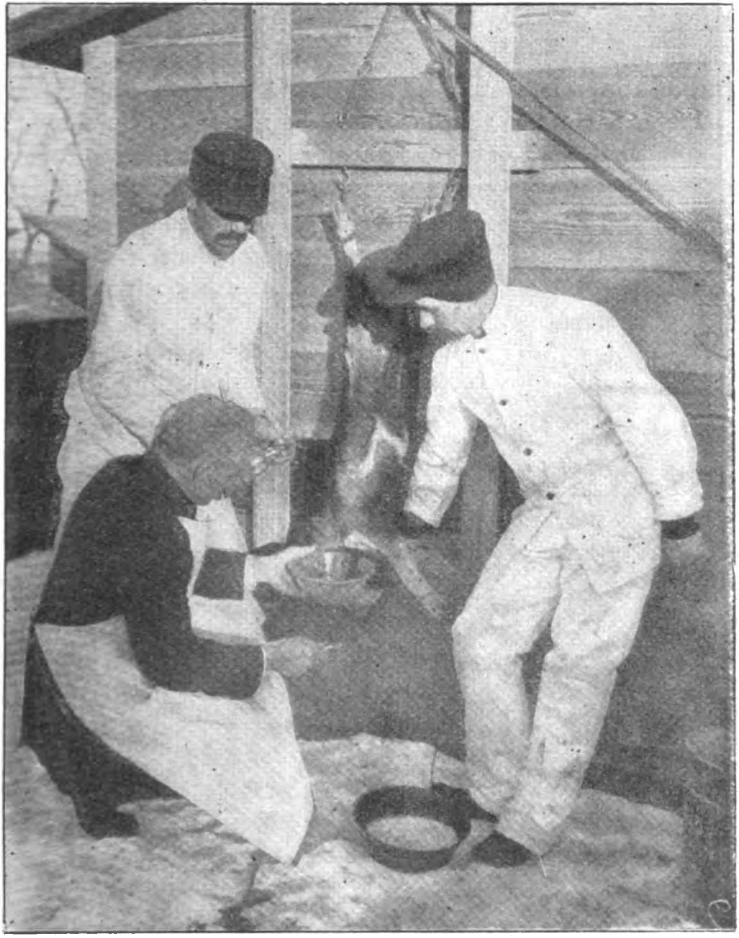

FIG. XII. Bleeding a pig about to die with the cholera. The defibrinated blood will be used either for hyperimmunizing or for vaccinating healthy hogs.

When a hog has died quickly within a few days after taking the disease, the kidneys frequently show dark spots on their surface, as shown in the illustration (fig. VI). These resemble the spots on a turkey egg. Parts of the lungs may be found solid and dark, resembling liver, or may show dark spots on their surface like those on the kidneys. The spleen is usually larger than normal. The lymphatic glands, especially those along the intestines, are usually enlarged and red. The intestine may contain blood or bloody feces.

In chronic cases, in which the hog lingers for a longer period before death, some of the above conditions show prominently while others do not show so well. In these cases ulcers are found on the inner lining of the large intestine, which may be an inch in diameter, or there may be many smaller ones, but as a rule, these do not show so well in the more acute forms of the disease. It seldom happens that all these conditions are found in the same animal, but any two of them are usually enough to warrant the diagnosis of hog cholera, and when the ulcers in the intestines are found they are positive evidence that it is cholera.

THE FOLLOWING BULLETINS

ARE AVAILABLE FOR DISTRIBUTION.

No. 12....Preliminary Experiments with Fungicides for Stinking Smut of Wheat.
No. 13....Experiments with Oats.
No. 15....Additional Experiments and Observations on Oat Smut.
No. 16....Experiments with Sorghum and with Sugar Beets.
No. 52....Kansas Weeds—Preliminary Circular on Distribution.
No. 120....Tests of Forest Trees.
No. 121....Treatment and Utilization of Flood-damaged Lands.
No. 129....Kansas Mammals in their Relation to Agriculture.
No. 136....Press Bulletins Nos. 125-151.
No. 137....Variations in the Test of Separator Cream.
No. 138....Effect of Bacteria in Wash-water of Butter.
No. 139....The Study of Corn.
No. 140....Milking Machines.
No. 141....Commercial Seeds of Brome-grass and of English and Kentucky Blue-grasses: Adulterants and Substitutes and their Detection.
No. 143....Disposal of Dairy and Farm Sewage, and Water Supply.
No. 144....Small-grain Crops.
No. 145....Spraying.
No. 148....Law Regulating the Sale of Commercial Fertilizers.
No. 149....Prevention of Sorghum and Kafir-corn Smut.
No. 150....The Hen's Place on the Farm.
No. 153....Deterioriation of Red Texas Oats in Kansas.
No. 154....The Mound-building Prairie Ant.
No. 155....Alfalfa.
No. 158....Anaylses of Registered Feeding-stuffs.
No. 160....Cow-peas.
No. 161....The Influence of Depth of Cultivation upon Soil Bacteria and their Activities.
No. 162....The Marketing of Eggs.

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Kansas State Agricultural College.

EXPERIMENT STATION.—Bulletin 165.

ED. H. WEBSTER, *Director*.

FARM BULLETIN.

DIVISION OF FORESTRY.

ALBERT DICKENS, *State Forester*.

Report of

State Forester upon Forest Conditions in Central and Western Kansas.

MANHATTAN, KAN.
MARCH, 1910.
1897

DIVISION OF FORESTRY.

ALBERT DICKENS	State Forester.
ROBT. E. EASTMAN	Assistant Forester.
CHRISTIAN JENSEN	Assistant in Charge Dodge City Forestry Station.
F. J. TURNER	Foreman, Ogallah Forestry Station.

FORESTRY has been one of the important lines of investigation since the early days of the Agricultural College, and some of the first experiments authorized by the Experiment Station were investigations of the growth of forest trees. These lines of work have been continued, and the work along forestry lines now includes:

1. Observations concerning the adaptation of species to Kansas conditions, plantings made at various dates from 1874 up to the present time being under observation.
2. Measurements of the rate of growth of various species.
3. Methods of propagation.
4. Influence of transplanting compared with trees grown from seed and not transplanted.
5. Investigation of the distribution and value of native species.
6. A study of the causes of success and failure of artificial forests.
7. The value of various species for windbreaks, for commercial plantations, and as ornamental trees.

Since May, 1909, the Forestry Stations at Ogallah and Dodge City have been under the care of the Department, and a special study of the forest conditions of the state has been commenced. A part of the state forestry work is the investigation of the fitness of soils and locations for forest trees. The preparation of plans for plantings and for the management of wood lots is being undertaken.

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THE NEW FORESTRY LAW.

The recognized need of a vigorous forestry policy and an aggressive campaign for tree planting on every farm in Kansas prompted the legislature of 1909 to pass the following forestry bill, which was signed by Governor Stubbs on March 8 and became effective on March 15, 1909:

SENATE BILL No. 231.

AN ACT to establish at the Kansas State Agricultural College a division of forestry under the direction of the board of regents of that institution, and appropriating funds for the support of same, and repealing chapter 405 of the Session Laws of 1907.

Be it enacted by the Legislature of the State of Kansas:

SECTION 1. For the promotion of forestry in Kansas there shall be established at the Kansas State Agricultural College, under the direction of the board of regents, a division of forestry. The board of regents of the Kansas State Agricultural College shall appoint a state forester who shall have general supervision of all experimental and demonstration work in forestry conducted by the Experiment Station. He shall promote practical forestry in every possible way, compile and disseminate information relative to forestry, and publish the results of such work through bulletins, press notices, and in such other ways as may be most practicable to reach the public, and by lecturing before farmers' institutes, associations and other organizations interested in forestry.

SEC. 2. The state forester shall employ, under the direction of the board of regents of the Kansas State Agricultural College, such assistants, who shall be practical foresters, laborers and clerks, and shall purchase necessary office furniture and equipment as may be needed to carry into effect the purposes of this act.

SEC. 3. The state forester shall, upon request, coöperate with towns, counties, corporations and individuals in preparing planting plans and plans for the protection, management and replacement of trees, wood lots and timber tracts under an agreement that the persons obtaining such assistance shall pay the field expenses of such work.

SEC. 4. The board of regents of the State Agricultural College may also conduct on the Dodge City and Ogallah Stations other demonstrations and experiments of local interest, such as seed breeding and tillage experiments, whenever such demonstrations may not interfere with the work in forestry.

SEC. 5. For carrying the provisions of this act into effect there shall be appropriated from moneys in the state treasury, not otherwise appropriated, the sum of one thousand dollars for the fiscal year ending June 30, 1909; two thousand dollars for the fiscal year ending June 30, 1910, and two thousand dollars for the fiscal year ending June 30, 1911. All vouchers for salaries and other expenses shall be paid in the same manner as expenses of the Kansas State Agricultural College.

SEC. 6. The Forestry Stations at Ogallah and Dodge City shall remain the property of the state for the purpose of conducting experimental and demonstration work in forestry under the direction of the board of regents of the State Agricultural College, who shall have all power in relation thereto now exercised by the Executive Council. And for the purpose of maintaining said Stations and for the purchase of trees, plants, seeds and cuttings, and for the payment of other incidental expenses, there is hereby appropriated the following sum, or as much as may be necessary, to wit:

For the Station at Ogallah.

For the fiscal years ending June 30, 1910, and June 30, 1911:

	1910	*1911*
Maintenance and repairs	$500	$500
For the purchase of trees, seeds and cuttings	300	300
For labor	1,200	1,200
For postage, freight and incidentals	200	200
	$2,200	$2,200

For the Station at Dodge City.

For the fiscal years ending June 30, 1909, June 30, 1910, and June 30, 1911:

	1910	*1911*
Maintenance and repairs	$500	$500
For the purchase of trees, seeds and cuttings	300	300
For labor	1,200	1,200
For postage, freight and incidentals	200	200
	$2,200	$2,200

For the Dodge City Station $500, or as much thereof as may be necessary, for the purchase of a team, said sum to be available at once.

SEC. 7. Chapter 405, Session Laws of 1907, and all acts and parts of acts conflicting with this are hereby repealed.

SEC. 8. This act shall take effect and be in force from and after its publication in the official state paper.

I hereby certify that the above bill originated in the Senate, and passed that body February 27, 1909.

W. J. FITZGERALD,
President of the Senate.

Z. E. WYANT,
Secretary of the Senate.

Passed the House March 8, 1909.

J. N. DOLLEY,
Speaker of the House.

C. H. BRILHART,
Asst. Chief Clerk of the House.

Approved March 12, 1909.—W. R. STUBBS, Governor.

STATE OF KANSAS,
OFFICE OF THE SECRETARY OF STATE.

I, C. E. Denton, secretary of state of the state of Kansas, do hereby certify that the above and foregoing is a correct copy of the original enrolled bill now on file in my office.

IN TESTIMONY WHEREOF, I have hereunto subscribed my name and affixed my official seal, this 13th day of March, 1909.

[SEAL.] C. E. DENTON,
Secretary of State.

At the first meeting of the board of regents after the passage of the bill, as a preliminary measure to get the new work under immediate headway, Albert Dickens, professor of horticulture and forestry at the Kansas State Agricultural College, was appointed state forester. A reorganization of the work at the Dodge City and Ogallah Stations was at once undertaken in conformity with the provisions of the law. Mr. Christian Jensen, a man of experience and training in forest nursery and tree-planting work, was selected as assistant forester and placed in charge of the Dodge City Station. Mr. Jensen had received his training in forestry at the Biltmore estate, Asheville, N. C., under Doctor Schenck, and had several years' experience in nursery work in Iowa and Kansas. Mr. Turner, a practical farmer and a man of considerable experience in nursery work, was employed as foreman of the Ogallah Station. The efficient work that these men accomplished is described in the following pages of the bulletin.

The appointment of Professor Dickens as state forester was recognized by him as a temporary arrangement until such time as he could recommend the appointment of a permanent state forester who could devote his entire time to the work. The Forestry Service of the United States Department of Agriculture was asked to recommend a man who had the ability and training to undertake the duties of state forester as prescribed by the law. Very happily the regents were able to secure the man recommended by the Forestry Service. Professor Dickens recommended that the forestry work be put on an independent basis, and the plans as outlined by him were submitted to the Forestry Service. Their recommendation was made in the following words:

"We heartily approve of your suggestion of putting forestry on an independent basis at the College and of the plans you have outlined for handling the subject. It gives us great pleasure to be able to recommend to you a man whom we are very glad unqualifiedly to indorse. He is Charles A. Scott, professor of forestry at the Iowa State College, Ames, Iowa. Professor Scott is a native Kansan, and a graduate from the agricultural course at Manhattan in 1901. Immediately after graduation he entered the forest-service work and, with the exception of one year spent at the Yale Forest School, he was in the service continuously until the fall of 1907. During this time he was engaged principally in tree-planting work in Nebraska, South Dakota and Kansas, although he also had some experience in other regions. From 1903 to 1907 he was in charge of the Nebraska and Kansas national forests, a place of considerable responsibility. In the fall of 1907 he was elected to his present position at Ames, where he has done excellent work, both in teaching forestry and in studying forest conditions in Iowa. Professor Scott meets people well; is used to public speaking and farmers' institute work; has executive ability, and is in every way a strong, clean, capable man."

At the January, 1910, meeting of the board of regents Professor Scott was elected state forester, and he has accepted and will enter upon his duties as soon as he can complete his work at the Iowa Agricultural College, not later than June 1, 1910.

The work at the Stations at Dodge City and Ogallah will be supplemented by extensive work to be conducted at the Fort Hays Branch Station.

The office of the state forester will be at Manhattan, Kan. Every farmer, town, county, school board or corporation interested in tree planting should address the state forester for information.

The following report submitted by Professor Dickens gives the results of his work at the Ogallah and Dodge City Stations under the new law, and sums up his experience of twenty or more years of careful observation and study of the forest conditions in central and western Kansas, and his conclusions on these matters may be accepted as entirely trustworthy.

H. J. WATERS, *President.*

Report of the State Forester.

By ALBERT DICKENS,
Professor of Horticulture and Forestry, and State Forester.

THE forestry work that has been done in central and western Kansas in the past quarter century has resulted in a large number of good tree plantations, many poor ones, some total failures and as might be expected a great variety of opinions concerning the possibility of growing forest trees in the various soils and situations found in the state. Theories, opinions and notions are easily manufactured. Frequently more ardor is exhibited in defending a notion than in securing facts, but the lessons that are valuable for the present and future settlers on the plains of Kansas must be drawn from facts.

Explanations concerning the treelessness of Kansas prairies have been plentiful, varying from the effects of wind and sun to the presence in the soil of substances and organisms which are fatal to tree growth, but any explanation that in any degree explains must give large measure of importance to the effects of fire.

Early settlers remember the story of an old Indian who was the last of his tribe to leave the head-waters of the creeks now known as the Kiowas, how they attempted to discourage winter visits of northern tribes by burning the prairies north of the Arkansas. The deer and buffalo would desert the burned tracts and the roving Indian would find no pasture for his war horse or pack pony. Other years his northern neighbors reached the river with a friendly north wind and then the fire raged to the creeks of the Cimarron watershed. And all the time the fire was the factor that kept the timber growth from encroaching upon the domain of the prairie. In central and western Kansas, the natural timber is restricted to very narrow belts along the streams.

Wherever the banks were sufficiently broken to check the fires, timber grew. Numerous examples of this might be given, taken from many localities. A striking example is furnished by Cedar Bluffs, in southern Trego county. The Smoky Hill river runs along the foot of the bluffs, cutting very close to the rocky ledge at each point of a crescent, the points being

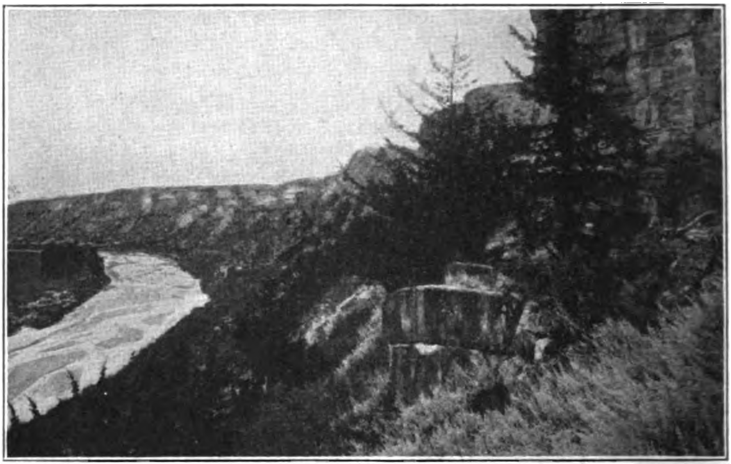


Plate 1. Red cedar can stand any hardship except fire.

something over a half mile apart. The limestone bluffs rise almost perpendicularly to heights of from fifty to one hundred feet, furnishing in combination with the river a very efficient protection from fire. In this protected spot, high above the stream, the red cedar has for ages declared its ability to withstand any hardship except fire.

In Hodgeman county, Buckner creek furnishes another example. The creek has cut through the deep soil, leaving occasional high banks, and in the creek bed good growths of hackberry, elm, willow and cottonwood are common.

Plate 2. Timber on Buckner creek, Hodgeman county.

The Arkansas and Cimarron rivers and their Kansas tributaries flow for the greater part of their lengths through alluvial soils. There are few rocky ledges and few high banks, and for the most part the prairie grass grows up to the very edge of the low bank. Wherever banks or broken surface afford protection, trees were found.

The need of the early settler for fuel was imperative. The wood contract was necessary for the existence of the frontier army post, and the few trees that might have produced seed for extending the forest area of Kansas were cut to provide for the soldier and settler. The vicinity of every army post has the same story. Mulberry creek and Crooked creek provided for Fort Dodge; the Pawnee and Walnut creeks for Fort Larned.

PLATE 8. Black walnut on Crooked creek, Meade county.

At Fort Hays, the limits of the old reservation may be easily noted by the trees which were preserved by the government. The wood contracts were filled from the land outside the reservation, and nearly every tree large enough to make fuel was sacrificed to provide for the advance guard of civilization.

A distance of forty-five miles seemed to mark the limit of profitable wood contracts, and on Crooked creek, about that distance southwest of Fort Dodge, some few of the big trees, mostly hackberry and black walnut, are still standing. The few that escaped the ax of the pioneer are those whose form made them hard to work for fuel and difficult to split into posts.

One of the largest of the black walnut trees measures four feet in diameter at five feet from the ground, and is fifty feet high. Like most large trees in western Kansas, it exhibits the type which is best fitted to survive under such conditions, short trunk with a widespreading top which protects the stem and the soil about it from the burning sun of summer. In one locality where the land adjoining Crooked creek has been protected from fire for a quarter century the timber is making considerable headway in its contest with the prairie.

Since the prairie fires have been restricted and the fuel need of the settler supplied by the coal miner and freight car, the area of natural timber has increased at a most gratifying rate. Thirty years ago the Arkansas, west of Hutchinson, and its tributaries from the south, were practically devoid of trees. To-day there are many acres that are under forest conditions and the forest area is increasing. Most of this growth is cottonwood and willow, species that produce large quantities of seed that is blown long distances and germinates very soon after ripening. Species that produce heavier seeds are not so readily distributed, and the time required for their distribution over a given area is very much greater. With Nature's slow methods centuries of the most favorable conditions would probably be required to extend the area of heavy-seeded species, but as the forest area increases the forest inhabitants—birds, squirrels and other animals—increase in numbers, and these agents of distribution help, very slowly but surely, in the introduction of other species. The increase of forest area in the past has been confined for the most part to the alluvial soils of the valleys; soils easily changed from prairie to forest because the soil is easily penetrated by roots and well adapted to nearly any forms of plant life.

Nature extends the forest back from the streams along ravines and broken surfaces, and works from these back into the upland prairie. The struggle for existence between prairie and forest is a bitter one. The species is indeed fit to survive that can compete for existence with the drought-enduring buffalo grass. But in the few localities where the buffalo grass has been deprived of its allies, fire and cattle, the forest is making progress. A few years' growth of buffalo grass accumulates, the rainfall is held for a longer time by the mulch on the soil, the buffalo grass itself grows stronger and roots deeper, but its prosperity augurs defeat, for the bunch grass

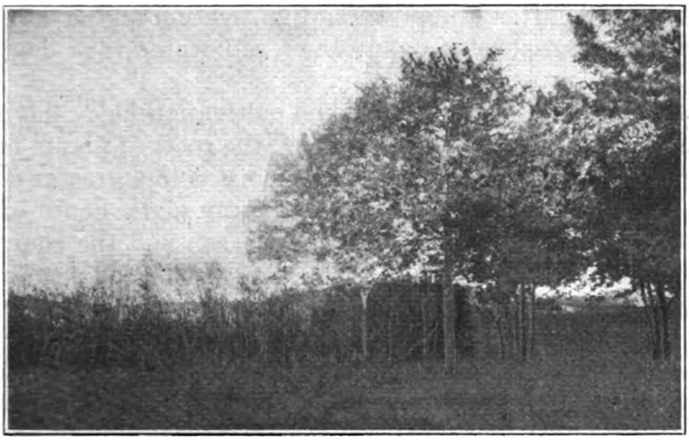


PLATE 4. Following the bunch grass the trees proclaim their title to the soil.

encroaches, then takes possession, and is succeeded by blue stem, the roots ever growing deeper and the soil mulch heavier. Very little rainfall now escapes. The buffalo grass lying close to the ground, packed by hoofs and baked by sun, held little water; but now the drought cannot wilt the blue stem with its roots five feet deep, making a way for the soil water. Then the shade from the trees, which have all the time been gaining in size, favors the horseweed, the buckbush and sumac appear, and these make a nurse crop for the tree seed; and up the slope, following the bunch-grass scouts and the skirmish line of sumac, the forest trees proclaim their title to the soil. The sermon they preach over and over is that even the dryest, hardest soils may grow trees if only the soil be prepared for their needs. The difference in the adaptability of soils for trees was not easily appreciated by the early settlers, and the fact that on the uplands many failures resulted from even well planned efforts, has been discouraging. Later investigations concerning soil conditions have added to the knowledge of these soils facts which make it surprising that so many successes resulted from plantings made in soils so poorly adapted to their growth, and also the encouraging fact that most of the Kansas prairie soils improve rapidly with proper cultivation.

Professor TenEyck, of the Kansas State Agricultural College, in securing soil samples from high prairie where the buffalo grass was the only growth found it impossible to drive the soil tube or even a soil augur deeper than two feet into the soil.

Yet such soils after a few years of cultivation and good farming show a measurable quantity of soil water to a depth of four or five feet.

The soil loosened by plowing and cultivation holds the moisture, which penetrates a little deeper; the roots of plants follow and open the way for more water to moisten to a greater depth. The length of time required to insure any given depth of soil moisture varies, of course, with the season and the character and composition of the soil, but in every soil good farming is the great factor in soil improvement.

It is now hard to realize that men seemed to expect the same results on the high buffalo grass lands as on the valley soils. But the optimism of the settler was too often pure enthusiasm with not even a trace of cool judgment. Many times a small hole was dug in the buffalo grass sod, a tree crowded into it, and when it failed to survive such a severe change of conditions the optimist turned pessimist and was sure that Nature had placed the ban upon tree life and that it was "flying in the face of Providence" and "combating Nature's irrevocable laws" to attempt to grow trees under such conditions. Often the tree was killed by supposed kindness. Water was poured into the small area of loosened soil, poured in frequently and abundantly and at great cost of time and labor, and the soil held the water, the tree stood in mud, with none of the life-giving oxygen in the soil about its roots, and it drowned.

A long drive in any of the western counties is certain to afford an opportunity to note how hard a struggle some trees can endure. Occasionally the long line of the prairie is broken by the survivors of a hedge row or line of road trees set in the days of the "first invasion" of the cattle country, in the later eighties. Set in a narrow strip of breaking that marked the line of the "claim," neglected for years, they have been pro-

PLATE 5. The story of hard times that are gone.

tected only by the deeply worn ruts of a trail which forms a poor substitute for a fire guard. In hot dry summers they were browsed by cattle, hungry for something besides the brown buffalo grass, and in winter were gnawed by horses high as the starving creatures could reach. Their poor misshapen trunks and bush-like tops tell the story of hard times that are gone. They are sad reminders of the day when optimism ran riot and theories of agriculture expounded by novices fresh from the office and shop were rife in the land.

PLATE 6. The story of trees planted by the man who tried.

On the opposite page of the prairie, a page made of the same material and exposed to the same sun and wind and storm, is written large the story of the trees planted by the man who tried. The man who used thought rather than theory, and who in the hard years gave the soil opportunity to secure every ounce of moisture that fell, and then worked to help the soil hold it.

There are enough successful plantations throughout the West to furnish lessons for future planters.

A study of the successes and failures resulting from the plantings made in western Kansas forces the conclusion that the factors which determine success or failure are, soil preparation, selection of species and condition of tree when set. The seasonal variation, particularly as regards rainfall, constitutes a factor of uncertainty, but with the three controllable factors all favorable there have been very few seasons when tree plantations have not attained a very fair measure of success.

In 1887 the legislature established two Stations for work in forestry, one about one and one-half miles west of Ogallah, in Trego county, and the other nearly three miles east of Dodge City, in Ford county. Both of these Stations are located on high prairie land that is representative of the greater part of the western third of Kansas.

The work of these Stations for the most part has been that of growing and distributing forest-tree seedlings to citizens of the state.

It is quite evident that the plantations at these Stations have not always received the best of care, for in some tracts the grass has encroached upon the plantations and only the hardiest species have had sufficient vitality to survive the struggle. Cultivation ceased before the trees were of sufficient size to shade the ground and prevent the wind from blowing the leaves from the site of the plantation.

In one or two cases fire has evidently burned over part of the plantation, destroying many trees and all the soil cover. Considering the hardships endured by these plantations they offer great encouragement to the citizen who wishes to make his home in western Kansas a place where life may mean more than the mere making of money.

The visitor at these Stations usually notes with some surprise the vigor of the evergreens. These were planted so far apart that they have not served to protect each other and so secure the most desirable form.

RED CEDAR.

The red cedar at Ogallah was brought from Cedar Bluffs, about twenty miles southwest of the Station. In their earlier

Plate 7. Ogallah Forestry Station.

years they evidently became the victims of someone with a mistaken idea of beauty in tree form, and were shortened in to become globes or cones. They have in some degree outgrown the mutilation, but it is not possible to compare their rate of growth with the pines. They are, however, thrifty and vigorous even though the buffalo grass for several years disputed their right to the ground they covered. The cedars at Dodge City have been more fortunate than the ones at Ogallah, in that they have never been mutilated. They compare well with other species in rate of growth and offer an object lesson in the value of this species for western Kansas planting.

PLATE 8. Dodge City Forestry Station.

The red cedar is the only evergreen tree native to Kansas, but it is, or has been, widely distributed over the state. All along the valleys of the Kaw and its tributaries even yet an occasional group of this species may be found. The word "cedar" is part of the name of a number of places in the state: Cedar Bluffs, in Decatur county; Cedar Vale, in Chautauqua county; Cedar Point, in Chase county, are evidence of its wide distribution. On the older maps of the state the short range of limestone bluffs in Trego county bear the name "Cedar Bluffs," and in early days many a canyon in Barber and Comanche counties bore local names denoting the fact that cedar posts were a resource after the buffalo bones had all been collected and hauled to the shipping points on the various railroads. Every citizen in central and western Kansas whose memory reaches back thirty years or more well remembers the trade in cedar posts, which kept the wolf from the door of many a sod shanty, but was disastrous to the forest area of southern Kansas and northern Oklahoma. Many young trees from these cedar tracts were carried by the cedar "rustlers" to the homesteads in distant counties and frequently were sold in the towns; when sufficient care was taken in packing and planting them, they have in a measure atoned for the depredations that left only stumps in canyons that formerly grew fine trees. Many were hauled a hundred or more miles, piled high upon a load of posts and exposed to wind and sun, and when set could produce only loss and discouragement. But enough have survived to demonstrate in every county that red cedar deserves a place high in the list of trees fitted to endure the most trying conditions.

AUSTRIAN PINE.

The Austrian pines have done bravely and have been particularly successful, making finely formed trees in spite of their constant exposure to the wind. They have made a regular growth and demonstrated their great value for planting in locations where trees are most needed. Occasional specimens have been noted in other localities, and in every case their hardiness and success have been most gratifying. The rate of growth during their early years is slow; it is never rapid, but the growth of an evergreen is always effective. Their work is done most economically. The central trunk grows true and straight, the side branches protecting the trunk from sun and wind.

At both Stations the Austrian pines have attained a height of twenty-two feet and a diameter of four inches at four feet from the ground. An encouraging observation is that which records the rate of growth as increasing as the trees attain greater age.

The same conclusion is drawn from measurements taken of trees on other plantations. Near Offerle, on high prairie soil, where the water is sixty feet below the surface, a little plantation made thirty-five years ago contains twenty-two trees planted fifteen feet apart. These trees now measure thirty feet in height and 8.7 inches in diameter.

A good Austrian pine is a handsome tree. Single specimens or groups make the finest of lawn trees and add much to the appearance of any home.

SCOTCH PINE.

The Scotch pine has not been so widely planted in the western part of the state, but where planted compares very favorably with the Austrian in rate of growth and hardiness. The young trees are somewhat more slender in their growth than are the Austrian pines and the trunks of single specimens are liable to be crooked and ill-shaped. But where planted in sufficient numbers to protect each other the Scotch pine is a very valuable tree.

The spruces have been less successful than the pines and red cedars. A few trees at the Dodge City Station have done fairly well, and for lawn planting they deserve further trial. All observations seem to indicate that they are much less desirable for western planting than the pines and cedars.

PLATE 9. Red cedar at Glover Park, Bluff City.

For ornamental purposes evergreens are unsurpassed, offering as they do the same general good appearance throughout the season. The red cedar is not quite so handsome throughout the year, as in dry, cold winters the foliage often assumes a brownish-red tint, which in close view is not so desirable as the pure green of the pines. For park and lawn planting the pines are rated as superior to the cedar for the eastern part of the state. But the hardiness of the red cedar recommends it for the ornamental plantings throughout the central and western part of the state. At Glover park, near Bluff City, Kan., some very fine results have been obtained with the red cedar. Trees planted in 1888 made a growth in height of practically one foot each year and are handsome, well-grown specimens. It is sometimes necessary in order to secure a symmetrical, well-formed tree to pinch back a branch that is making too rapid growth, but heavy pruning of evergreens should never be allowed. The natural form of the tree is vastly superior, both from a practical, commercial point of view and landscape effect, to any form that may be secured by severe pruning.

These evergreens are the best trees for windbreak purposes, they are at work all the year, and while their growth is not rapid they have demonstrated their hardiness and ability to withstand any hardship except fire, when once they are well established in the soil.

I am well aware that many settlers have had many discouraging failures result from their attempts to grow the various species of evergreens. As a rule high prices were paid for the little trees, and they were set with fond hopes and happy expectations of the improvement the trees would work in the appearance of the home.

In many cases the hopes were short-lived, and the planter saw his trees fade, and when they assumed the brown color of the buffalo grass he remembered the oft-repeated prophecy of the deposed ranchman, "The desert will come back and claim its own," and as he saw the leaves drop and next winter only the bare stem where he had hoped for a beautiful snow picture of green and white, he feared the prophecy was a true one. The great cause of loss in planting has been due to the fact that when the roots of these species become dry the gummy sap hardens in the tissue, or even exudes and forms a coat about the roots, enclosing each in a water-tight compartment. The little tree may hold its color for some time, but no root growth is possible. Unless carefully protected from sun and air every moment of the time it is out of the soil the chance for its success is very small.

Packing in wet moss should always be practiced, and whenever possible the tree should be "balled"—the soil in which the roots have grown taken up with the tiny tree and taken with it to its new location.

The best success in growing evergreens has been secured by procuring the seedlings, and setting them in nursery rows, the trees being a foot or more apart in the row. The row should be partially shaded until they are well started at least, and in very trying seasons it is well to continue the shade throughout the summer and early fall. The nursery row must be well cultivated and the soil kept in good condition. After a year or two in the nursery row the trees may be moved to the location desired with little danger of loss. The best plan is to take quite a ball of the earth with the tree, and carefully set earth and tree in a hole previously dug.

The best results have followed the setting of young trees moved in winter with the earth frozen about the roots. With trees 18 to 24 inches high a good method is to plow a deep furrow each side of the row and then cut down between the trees with a spade. A mulch of wet straw or hay is applied to prevent the soil becoming dry, and when frozen the chunks of soil may be pried out with a bar and the tree taken to holes dug in the fall before the ground is frozen. Some soil is stored in cellar or barn, or a pile of it covered with hay, to use in filling in about the frozen ball. The Experiment Station has shipped trees thus handled to Fort Hays Branch Experiment Station, and a very high degree of success has always followed the use of this method.

DEMONSTRATION PLANTINGS.

Demonstration plantings were inaugurated at both of the Forestry Stations. The most extensive ones were made from 1889 to 1892. These were set in rows eight feet apart and cultivated for some years. Observations made in 1909 as to the success and growth of the species planted note that for a good many years no cultivation has been given plantations at Ogallah. At Dodge the same condition prevailed for some years prior to 1908, when the sod was broken up and has since been worked into very fair condition in preparation for some extensive work in underplanting.

It is apparent that cultivation was discontinued before the trees were sufficiently large or numerous to shade the soil, and the grass has made quite a thick sod. In one or two places fire has evidently done some damage, but in spite of all the hardships and neglect some of the species have made a very fair growth and are now more than holding their own against the odds which have been so long against them.

GREEN ASH.

The green ash has fought a good fight at Ogallah in a block planted in 1892. The rows are remarkably even, and show nearly ninety per cent of the original number. Their heights vary but little except on the south edge, where the friendly south wind has piled soil and Russian thistles about them, and these trees are about four feet higher than the ones not so favored. The entire plantation averages slightly more than eleven feet high, and four inches in diameter at three feet. The best trees are sixteen feet in height and six inches in diameter. At Dodge City the ash are especially good, a number being over twenty feet high and five inches in diameter, the best reaching twenty-six feet and a diameter of seven inches. They are well formed and in every way desirable trees. The value of the ash as a shade and ornamental tree has been noted in many localities. Particularly effective use has been made of this species in the Glover park, at Bluff City, named in honor of Jas. Glover, who planned, planted and cared for it during its entire history. The trees on Ash avenue, planted in 1888, have attained a height of thirty feet, and are as uniform in shape, size and beauty as could be desired.

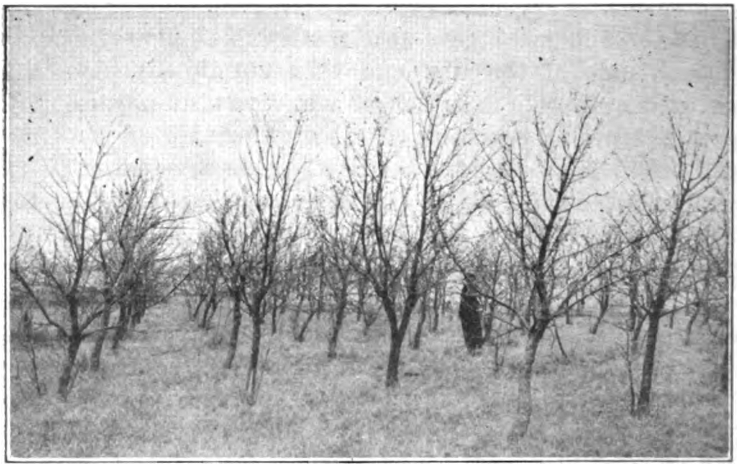


PLATE 10. Green ash at Ogallah Station.

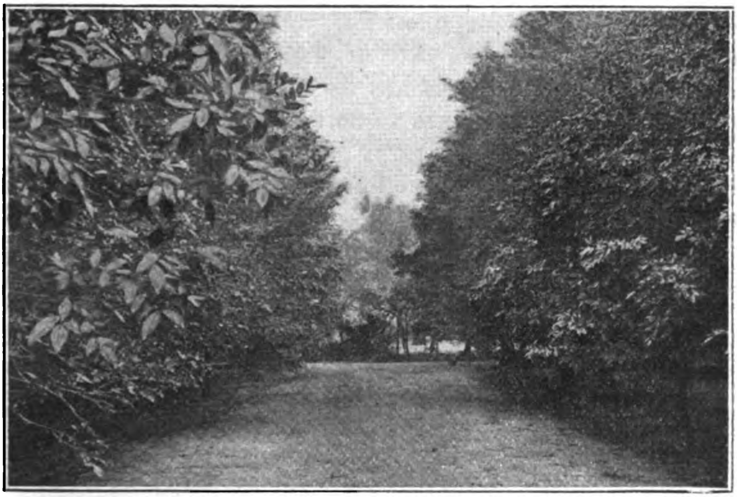


PLATE 11. Ash avenue, Glover Park.

BLACK LOCUST.

At Ogallah the black locust has fared badly. Borers evidently destroyed the original trees and fire has burned many of the sprouts, the best one now being a double trunk grown from two sprouts, each trunk being twelve feet high, and three inches in diameter at three feet. For many years the borer, known to entomologists as *Cyllene robiniæ*, has ravaged this species to such an extent as to make it seem unwise to recom-

PLATE 12. Black locust at Dodge City Station.

mend black locust for planting. Most plantations made in Kansas have shared the fate of the one at Ogallah, and this otherwise valuable species has been on the list of undesirable trees. It is a pleasant task to note at Dodge City the first encouragement for the owners of black locust plantings, and going from Dodge City west and south we have seen a number of plantings that confirm the opinion that black locust trees are likely to prove of ultimate profit to the planter. At Dodge City are a number of good trees, many still showing the effect of the borer's ravages, which have for a number of years been rapidly recovering from the injury, and are now strong, sturdy trees. A number of these trees at Dodge City are nearly thirty feet high and a foot in diameter at three feet from the ground.

In the city park at Anthony are a number of specially good black locust trees. They have evidently outgrown any injury

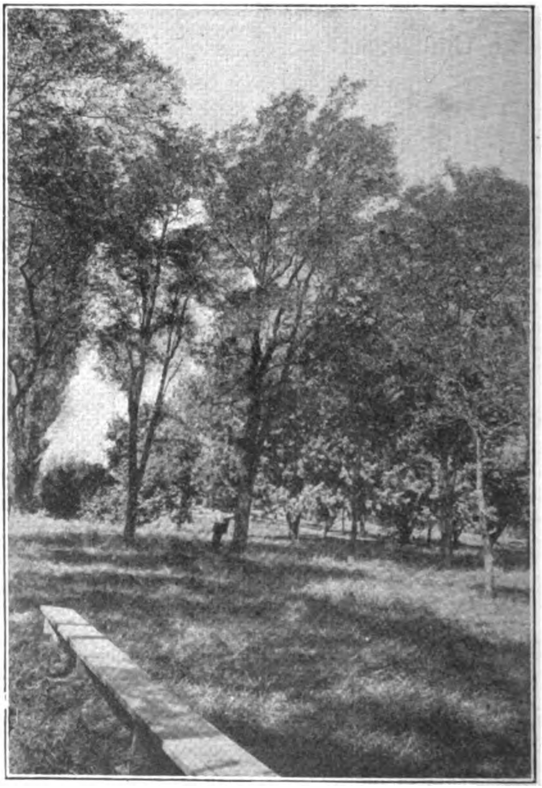


PLATE 13. Black locust, Anthony city park.

by borers and demonstrate the possibility of this species when well grown and free from insect injury. Some of these trees are fifty feet high, eighteen inches in diameter two feet from the ground.

Not many of the plantings made in accordance with the provisions of the timber culture or "tree-claim" act have added to the forest area of Kansas, but a few have been visited which by their success and the possible weight of their influence upon future plantings have certainly achieved what the authors of the bill hoped the law could accomplish.

PLATE 14. Black locust, McCauley timber claim.

The McCauley timber claim, about forty miles southwest of Dodge City, is one of these. The first plantings were made of cottonwood cuttings and box elder seedlings and were not successful. Black locust seed was planted in nursery rows, and the trees thus grown were used to replace the cottonwood and box elder. They made good growth for a few years, but were afterwards badly injured by the borers. Ten years ago the owners decided to cut it to the ground and found the posts and poles considerably worm-eaten, but they were so much in demand that the ten acres netted them nearly one hundred dollars per acre. The value of the fuel secured was considered equal to the cost of cutting. The brush was burned to check as far as possible the increase of the borers.

After ten years growth this plantation is in a most promising condition. The owner estimates the posts and poles as much superior to the cutting made ten years ago and the condition of the trees is all that could be desired. Many of them have a height of twenty-five feet and a diameter of three and a half inches.

A mile east of the McCauley timber claim is a plantation made in 1882 and still owned by Mr. Benj. Haywood. The ten acres consists for the most part of cottonwood and black locust. The soil is specially favorable for tree growth, being a rich sandy loam, and the trees have made a very creditable growth. A number of the cottonwoods are eighteen inches in diameter at four feet from the ground, and twelve inches in diameter at the height of twenty-five feet. Many are seventy feet high.

The black locusts have evidently outgrown the injury inflicted by insects during their early years, and the grove contains many fine trees of this species. A number measure over forty feet in height. Many would yield good poles twenty-four feet long, and a few good thirty-foot poles might be cut. Many average six inches in diameter and the best are eight inches through at four feet from the ground.

PLATE 15. Haywood timber claim.

HONEY LOCUST.

Of all the species tested in many parts of western Kansas, the honey locust is the most conspicuous success.

Its rate of growth is only moderate, but the rate is maintained for many years. A large proportion of the trees planted have good form, and they are strong in stem and branch, not often injured by wind or ice storms.

At the Ogallah Station a considerable number of honey locusts have been planted in the older groves and along the woods, and where given good care the records are very satisfactory. Many of these trees have reached a height of twenty feet and a diameter of five inches in fifteen years.

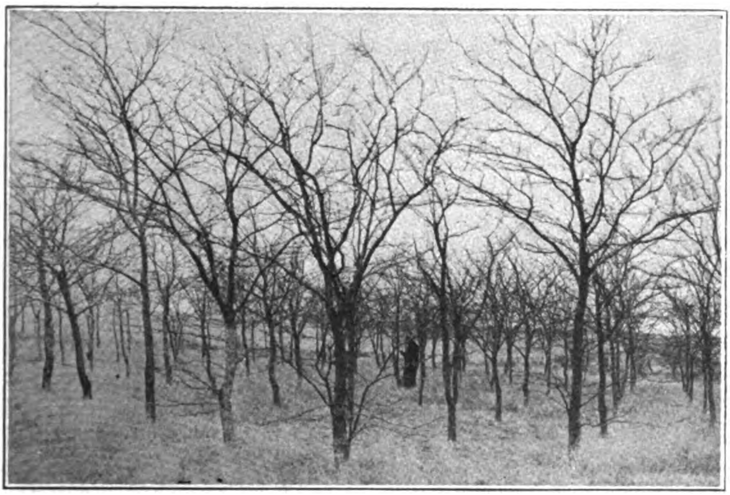


Plate 16. Honey locust at Ogallah Station.

In a demonstration block planted eighteen years ago and neglected for so long a time that the buffalo sod had gained a secure foothold the honey locust has made a very creditable growth. The best trees have reached a height of twenty-three feet and a diameter of six inches. At Dodge City the honey locust trees have done very well indeed. Some few trees have been the victims of some over-zealous pruner. Robbed of the foliage that nature had provided to protect the trunks, the hot sun has scalded the bark on the south and west sides of the tree. After the bark has been scalded borers find conditions favorable for their development and a few trees of this species, usually fairly free from such injury, have been killed by the combination of too heavy pruning, sun-scald and borers. The greater number of the honey locust trees at Dodge City have made very satisfactory growth. The best trees are thirty-five

PLATE 17. Honey locust at Dodge City.

feet high, and twelve inches in diameter. They are handsome, graceful trees, good specimens of this very desirable species.

OSAGE ORANGE.

The Osage orange is equally as hardy and resistant to all forms of tree troubles as the honey locust. It is not as rapid in growth, nor so certain to make trees of good form, but its value for posts, poles and fuel is widely appreciated. In spite of its faults it is well toward the top of the list of trees for localities where conditions are somewhat unfavorable for trees. The thorns and the habit of sprouting are its faults, and, while serious ones, they are readily overlooked by the planter who must first of all ask the question, "Will it live?" At Ogallah the Osage orange has lived up to its reputation. In the demonstration block, in spite of sod and at least one fire, over 120 of the original trees or strong sprouts from them are still vigorous. Fifty of these average over ten feet high and two and a half inches at three feet from the ground. The best are

PLATE 18. Osage orange at Ogallah Station.

fourteen feet high and three and a half inches in diameter. At Dodge City the Osage orange trees have been more fortunate. Located near a field that has evidently produced some corn husks, and more Russian thistles, the rows have been well mulched and the soil has blown into the mulch until the trees now stand in a ridge or bank from two to four feet high. A number of these trees are nineteen feet above the bank and four inches in diameter. They are valuable for many purposes, but too handsome and useful as trees to be sacrificed for any purpose, however important.

Occasional specimens have been noted in many trying localities that attest the hardiness and resistance of this species. The trail between Johnson City and Richfield passes an old hedgerow that, after being deserted for many years and browsed by live stock in severe winters, has a number of trees which show a very creditable growth. On the site of Fort Hays are a few Osage orange trees that were evidently conveniently located to serve as hitching posts. They are scarred and deformed, but after years of neglect they have repaid a little care by making a very fair growth.

At Garfield a row of Osage orange planted thirty years ago along the Santa Fe railroad presents a most valuable object lesson in the possibilities of this species as a windbreak and in the production of posts. A considerable number of posts have been cut in former years, and at present 1000 posts, many of them twelve inches in diameter, could be cut from 500 yards of this hedge. The value of such a windbreak, twenty-five feet high, is not easily computed if it surrounds a garden or fruit plantation.

BLACK WALNUT.

At Ogallah the black walnut shows the greatest variation in growth and success of any species. In the demonstration block, on the north side of the farm, the trees have been a total failure. Unable to endure the neglect, the encroachment of the buffalo grass and a fire, but five poor little trees are yet alive; the largest of these is only six feet high and one and a half inches in diameter. On the east line of the place, near the southeast corner, stand a few walnut trees where the nuts were planted twenty-five years ago by Mr. C. C. Yetter, the owner of the adjoining farm. They have benefited by the accidental mulch blown about them and by the soil which has drifted into the mulch from the adjoining fields.

These trees show in marked degree the form best suited for their survival—widespreading tops, which shade the trunk and the soil about it. The measurements of these twenty-one trees show quite strikingly the adaptability of trees to the conditions in which they grow. The spread of the tops is very much greater in proportion to their height than in trees of the same species under similar conditions in eastern Kansas. Where three or more trees are sufficiently close to protect the middle one, the middle tree runs up higher and puts less of its growth into protecting branches, but for the greater number, standing quite a distance apart, it has been a case of "each for himself." Of a number of black walnut trees observed in eastern Kansas, the proportion of height to spread of branches in trees which stand alone is about two in height to one in spread. These trees at Ogallah are very nearly equal. Some have a spread of branches considerably greater than their height. One tree of this row, ten inches in diameter at three feet from the ground, is but sixteen feet high, but has a spread of twenty-two feet. The best tree in the row has a diameter of fifteen inches, is thirty and one-half feet high, with a spread of twenty-four feet. The averages of the twenty-one trees in this row are: Diameter, nine and three-tenths inches; height, twenty and one-tenth feet; spread, nineteen and two-tenths feet. These figures may not mean much to persons who are accustomed to think of black walnut trees as forest giants, but anyone who has had experience in growing trees on high plains feels inclined to salute these squatty specimens as "squatter sovereigns"; and when one sees them bear a few bushels each of nuts and sees the satisfaction that the children of the short grass derive from a nutting party, and how a part of the nuts are saved for seed, he appreciates how great a power for good a few well-grown trees may be. For they are well grown—so well for their locality that they may well serve many coming generations of Kansans as models, and point the importance of taking the pains to plant the seed and care for the tree in the location in which it is to stand with its blessing and benediction for future generations. A few miles from the Dodge City Station a plantation of walnut trees standing where the nuts were planted has been making very satisfactory growth. The location is a favorable one, the slope of a ravine or draw that is rather steep for general farming, such a place as occurs on hundreds of farms all over the state, and which would be much more valuable and productive of much more good if planted to trees than in fodders or grains. This plantation has not been thinned, and considerable resemblance to forest condition has been reached in a surprisingly short time. The trees are in rows six feet apart and stand quite thickly in the row, shading the ground and preventing in great measure the growth of grass and weeds. In eight years these trees have

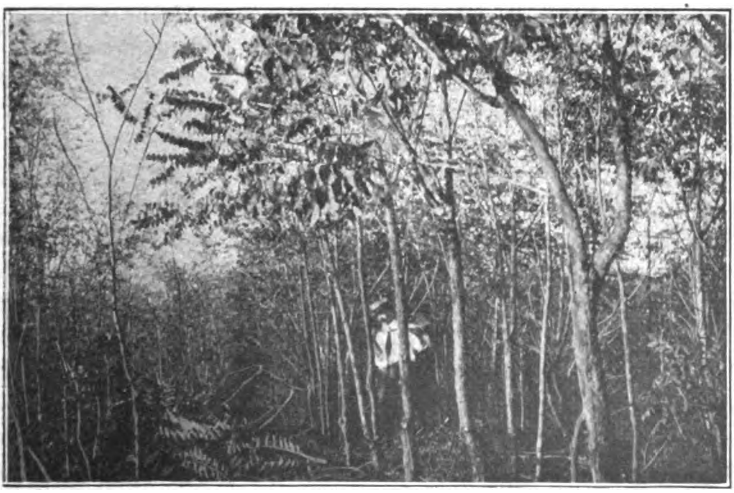


PLATE 19. Walnuts near Dodge City.

reached an average diameter of two inches at the ground and an average height of twelve feet. Some careful thinning would make this a very handsome grove in a few years' time.

The value of this planting of the seeds where the trees are to stand has been noted in Bulletin 120 of the Kansas Experiment Station, and for the more trying conditions of western Kansas it is especially recommended. All the nut trees form very strong tap roots. In the forest tree nursery work of the Kansas Experiment Station seedlings of hickory have been noted as making during the first season's growth a height of six inches, while the root reached a depth of thirty-six inches. With such habits of growth it is small wonder that the transplanting of these trees when they have attained a height of four or five feet usually results in failure and disappointment. Unless the tap root is cut and the formation of lateral roots induced while the tree is very young, it is useless to attempt to transplant a nut tree by ordinary methods.

A few miles north of Plainville, in Rooks county, is a planting of bur oak which is making an admirable fight against the encroachment of the prairie. Their vigor is doubtless due to the fact that their tap roots have reached deep down into the soil and are able to supply the tops with sufficient moisture to endure any degree of drought.

HACKBERRY.

The hackberry has not been very extensively planted, but the few trees at Ogallah sustain the reputation of the species for hardiness and vigor. These trees show a wide variation in form, some showing the symmetry and vigor of the eastern form, while others have the dwarfed appearance often noted in the hackberry trees in canyons of southwestern Kansas and northwestern Oklahoma. The eastern form seems not less successful than the western, the best trees measuring sixteen feet high and four inches in diameter, while the best of the western form are but twelve feet high and three and a half inches in diameter. The success of this species has been so general that it is quite certain that its planting will prove satisfactory and profitable.

ELM.

The white or American elm is generally hardy and its success has been very general. Its rate of growth is not rapid, but regular, and the adaptability of the species to conditions is not excelled by any tree yet tested. The widespreading low-topped form is most common, and the grower who attempts to prune western Kansas elms into an imitation of the Connecticut elms is certain to find that even this hardy species may be ruined by sun scald and insects.

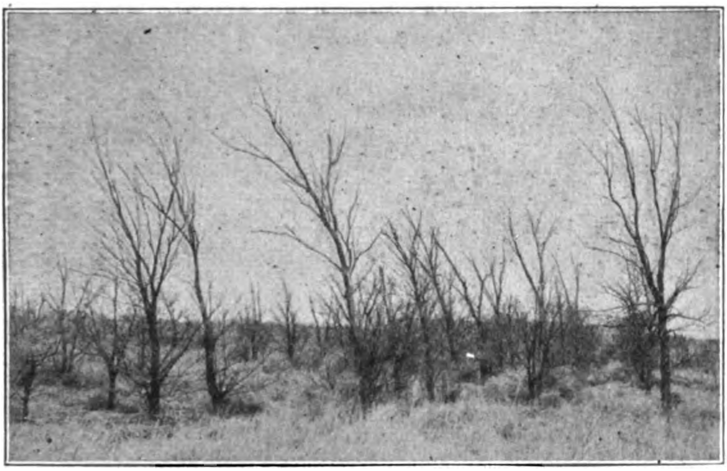


PLATE 20. White elm at Ogallah Station.

The elms in the demonstration block at Ogallah have been somewhat favored in their location, having been set in a slight depression in the high prairie. This slight difference shows with remarkable distinctness, the trees in the waterway being much larger and better than the trees upon the slope, the gradation being readily noticed. Twelve trees are above twenty feet in height and five inches in diameter, the best being twenty-five feet high and six inches in diameter. Occasional specimens have been noted in many parts of the state, and in every case where the trees have had even fair care a high degree of success has been attained. At Offerle, on high prairie soil, white elms have attained a diameter of eighteen inches, a spread of forty feet and a height of thirty feet. For shade and street trees the white elm is especially desirable.

COFFEE BEAN.

The coffee bean has proved able to adapt itself to a wide variety of soils and conditions. In eastern Kansas it is usually found near streams, but occasionally climbs to the higher parts of ravines and sometimes to the high upland. It has not been generally planted, but has succeeded in nearly every case where

PLATE 21. Coffee bean at Dodge City Station.

tested. At Ogallah the best trees are nine feet high with a diameter of three inches, and the trees show a vigor that is most encouraging. At Dodge City a greater number have been planted. The best are eighteen feet high and four inches in diameter. In a number of localities in the Arkansas valley its growth has been very satisfactory indeed, and it adds pleasing variety to lawn and park plantings.

RUSSIAN MULBERRY.

The success of the Russian mulberry has been quite varied, so much so that it is difficult to draw conclusions as to the wisdom of including it in a list for general planting. In northern Kansas it has been injured very frequently in severe winters. Young trees making vigorous growth have been killed back to the ground in many instances, and upon older trees the young wood is sometimes killed. The trees nearly always make a good recovery, but unless carefully trimmed they present an unkempt appearance, which is unpardonable in a lawn or street tree. At Ogallah the mulberry is very poor. A few have reached post size, but its behavior there will not warrant its being recommended for northern Kansas.

At Dodge City the mulberry has succeeded much better. Even the best trees branch near the ground and are thick-topped and shrubby owing to their having been winter injured, but in spite of this their growth has been such as to make them of considerable value for posts and poles. The best trees at Dodge City Station branch near the ground. Some of the best measure twenty-four feet high, and several individual trees would each produce a half dozen good posts and as many more stakes.

In the southern counties of the state Russian mulberry seems much less liable to winter injury. At Ashland, in Clark county, the courthouse square furnishes a very good illustration of the possibilities of this species for posts and poles. A row 400 feet long, now eighteen years old, would cut nearly 200 posts and as many fair stakes.

PLATE 22. Russian mulberry at Ashland.

The fruit is not of high quality, but is often used when other fruits are scarce, and as it ripens with the cherries and raspberries it seems to attract many birds from the more valuable fruits, and it is frequently planted in the windbreaks about fruit plantations with this end in view. The need of some careful selection and breeding of this species is clearly indicated. The species is quite readily grown from cuttings and the better individuals may be propagated and the uncertainty which attends the planting of seedlings be avoided.

The desirability of the mulberry as a street and lawn tree is lessened by the fact that the fruit attracts flies and birds, and causes the sidewalks beneath them to be in a very unclean condition, and as the fruiting season lasts a month or more the nuisance is a serious one.

The fact that the Russian mulberry is generally diœciously flowered makes it possible to avoid the fruit nuisance when this species is desired as a shade tree. By using cuttings from staminate flowered trees of desirable form and vigor a considerable degree of uniformity may be secured. At the fair grounds at Anthony, Kan., may be found a very fine illustration of the desirability of the "male mulberry" for shade and ornament. The trees are sufficiently uniform to make the appearance of the rows very pleasing and the rate of growth has been especially good, trees set four years ago having attained a height of fourteen feet and a diameter of four inches.

PLATE 23. Male mulberry at fair grounds, Anthony.

While most of the Russian mulberry trees are more or less irregular in form and many are decidedly crooked and ill-shaped, an occasional tree is sufficiently symmetrical and handsome to suggest the possibility of securing a uniform type by propagating from them by means of cuttings. One of the most handsome trees seen in southwestern Kansas is a mulberry tree, perfect in form and symmetry, on the farm of Jas. Lewis, about midway between Bluff City and Anthony.

One mulberry tree at Glover park, Bluff City, planted in 1888, has obtained the height of forty feet, a spread of forty-two feet, with a diameter of twenty inches two feet from the

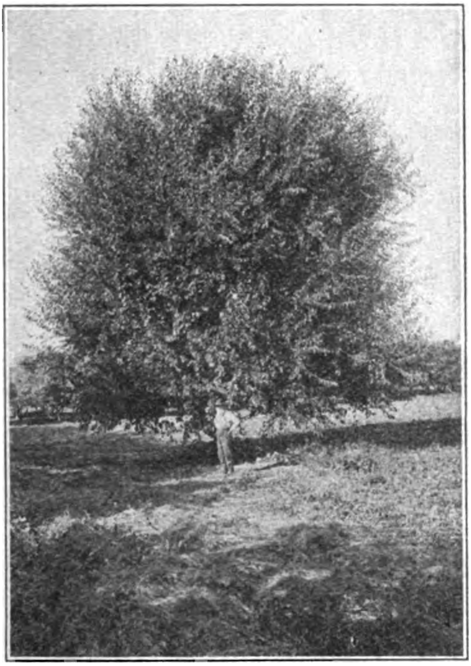


PLATE 24. Mulberry tree in Harper county.

ground, from there into five branches which aggregate three feet in diameter.

THE AILANTHUS.

The ailanthus, sometimes called "Tree of Heaven," is not of much value for any purpose, but its success is encouraging to tree lovers. At Ogallah the trees have evidently been killed back frequently and are poor specimens, but at Dodge City a number have made very fair growth and are now fairly good trees, twenty feet high and eight inches in diameter at three feet. The tropical appearance of the young trees when making a vigorous growth is quite effective and they have some value for park planting. The heavy masses of seed give the trees a striking appearance in summer, particularly when in ripening they assume a pink tinge unlike that of any other tree growth. The staminate blossoms, however, emit a strong odor which many persons find very disagreeable, and the pollen, produced in large quantities, is objectionable.

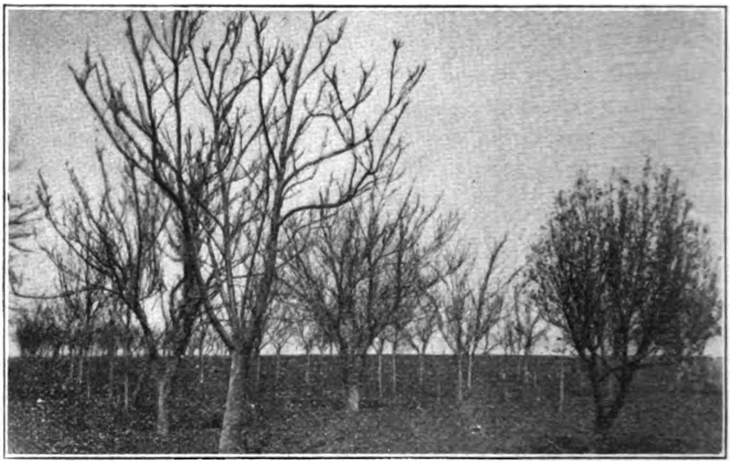


PLATE 25. Ailanthus at Dodge City.

RUSSIAN OLIVE.

The Russian olive while not a large tree is desirable on account of its hardiness and adaptability to trying conditions. The best one at Ogallah is twelve feet high, branches low, and with its soft, silver-gray foliage makes a very attractive tree picture. For lawn planting it is a very desirable addition to the list of hardy species, and when planted in groups near Osage, ash or other species with dark green leaves makes a very striking contrast.

COTTONWOOD.

The cottonwood and other species of the poplar group have not been particularly successful when planted upon the heavy soil of high prairies. At Ogallah and at Dodge City the poplar group is represented by a few dying trunks from which a few sprouts are growing.

At the Hays Station the young cottonwoods have made a very strong growth during the few years since planting, and furnish protection for species that succeed best in partial shade. Along the creek bank and in ravines where the soil is always moist the cottonwood is very valuable, producing in some cases very good sawlogs in twenty-five years. In sandy soils the cottonwood succeeds very well, and all along the valley of the Arkansas and its tributaries the cottonwood is making forests more rapidly than any other species. At Dodge

City, Garden City, and in fact wherever these trees have been planted in the valley, very good results have been recorded.

The trees in the Dodge City park were planted about twenty years ago. They now stand thirty feet apart and have reached a height of seventy to seventy-five feet with an average diameter of eighteen inches at four feet from the ground. Most of them branch low, but they make a very good form for groves for public gatherings.

Another planting noted about six miles southwest of Garfield, Pawnee county, about thirty years old, is a most excellent windbreak. The trees are planted in a double row, and in one stretch 225 feet long 77 trees have attained a height of seventy-five feet and a diameter of twelve inches at four feet, and would make very fair logs.

The ease with which the cottonwood grows from cuttings marked it as the poor man's tree and it was very widely planted by the early settlers. When located near a well or a watering place it always made the most of an occasional watering and produced trees of considerable size in a short time. A few settlers who systematically watered a row of these trees have been rewarded by a rapid growth that in a few years produces fine trees.

Wherever the soil is moist and somewhat sandy the cottonwood will make very fair returns, at present prices of lumber. Barrels for apples and sweet potatoes, crates for fruit and vegetables are needed in ever increasing numbers, and cottonwood lumber must be depended upon to supply a large part of this demand.

For park plantings the cottonwood should be grown from cuttings in order that the cotton nuisance may be avoided, and as it is the only species that can produce a large tree in a quarter century its value as an ornamental species is not easily overestimated. The cottonwood has been the pioneer tree; even on upland its growth has made the success of longer lived species possible, and on valley soils it has produced shade, fuel and sawlogs in less time than any other species in any locality where freezing weather occurs. It is worthy the regard of every tree lover and deserves a place in song and story not less honorable than the oak.

OTHER SPECIES.

The **Linden**, or *Basswood*, is represented at the Ogallah Station by a single stunted specimen. At Kinsley, Edwards county, six very fine specimens were noted which have made a height of thirty-five feet in twenty-five years. They are evidently very much at home and show every indication of being well adapted to their location.

The **Red** (or *Slippery*) **Elm** is not often found, but when set it has proved the equal of the white elm in hardiness and vigor. Its greater value should prompt tree growers to use this species more widely for western planting.

A single **Sycamore** at Ogallah has made but poor growth, but it is rather surprising that it has survived so long on high, dry land with but little care. Many fine sycamore trees have been observed in towns in the Arkansas valley, particularly at Great Bend and Hutchinson, and it is believed that this handsome tree is worthy of more extended trial. Several other less important species have been observed to be attaining fair success, among them are redbud, Sophora, persimmon, ironwood and China berry.

Box Elder and **Soft Maple** make a rapid growth and on moist, rich soils often make fine trees. The wood becomes brittle as the trees age and injury from the wind is very common. On high dry soils they have been short-lived, and are not recommended for upland planting.

CATALPA.

No tree has been the subject of so much discussion as the catalpa. Any mention of this genus should first distinctly set forth the fact that there are several species which, while quite similar in general characters, differ widely in adaptability to conditions and more in rate of growth and value.

The species of value is native in southern Indiana and Illinois, and is capable of enduring severe winter weather without injury; it also excels in rate of growth, form of tree and value for use any other species of the genus Catalpa.

The southern catalpa, now known to the botanist as *Catalpa catalpa,* formerly as *Catalpa bignonioides,* and the Japanese species *Catalpa kœmpferi,* seem to hybridize readily with the hardy catalpa, and the hybrids vary in size, form and value.

In the early years of catalpa enthusiasm these facts were not widely known and many plantings have been the cause of untold disappointment as well as great financial loss. Many of these trees have been seriously injured in severe winters and later made but slow, uneven growth. Others have been hardy but made only low shrubby growth. Moreover, the hardy catalpa when planted on dry or poor soil has not made a very successful growth, so that the general information concerning the catalpa is not very definite.

On good soils the hardy catalpa has been a very profitable and very satisfactory tree, producing a crop of posts and poles in from seven to ten years, and then renewing itself from the sprouts or coppice growth, sometimes producing a second crop in less time than that required for the first crop.

The catalpa trees planted at Ogallah and Dodge City were evidently the inferior species, and the soil and location being unfavorable for the catalpa the trees at these Stations are practically valueless.

So general is the interest in the catalpa and so urgent the need of general information that the following extracts from Bulletin No. 108 of the Kansas Experiment Station are reprinted here.

The genus Catalpa belongs to the family of the BIGNONIACEÆ. Of the six species, two, *C. catalpa* Karst. and *C. speciosa* Ward., are native to North America. Following are the botanical descriptions of the American species:

Catalpa catalpa (Linn.) Karsten.

Bignonia catalpa Linnæus, Spec. Pl., ed. 1, II, 622 (1753).
Catalpa bignonioides Walter, Flora Caroliniana, 64 (1788).
Catalpa cordifolia Moench, Meth. 464 (1794).
Catalpa ternifolia Cavanilles, Desc. Pl. 26 (1802).
Catalpa syringæfolia Sims, in Bot. Mag. XXVII, t. 1094 (1808).
Catalpa communis Du Mont de Courset, Bot. Cult., ed. 2, III, 242 (1811).
Catalpa catalpa Karsten, Deutsch Fl. 927 (1882).

"Flowers in many-flowered, crowded panicles; corolla thickly spotted on the inner surface. Fruit slender. Leaves slightly acuminate.

"A tree, rarely sixty feet in height, with a short trunk, sometimes three or four feet in diameter, and stout, elongated brittle branches, which form a broad head and dichotomous branchlets. The bark of the trunk varies from a quarter to a third of an inch in thickness, and is light brown tinged with red on the surface, which separates in large, thin, irregular scales. The branchlets, when they first appear, are green shaded with

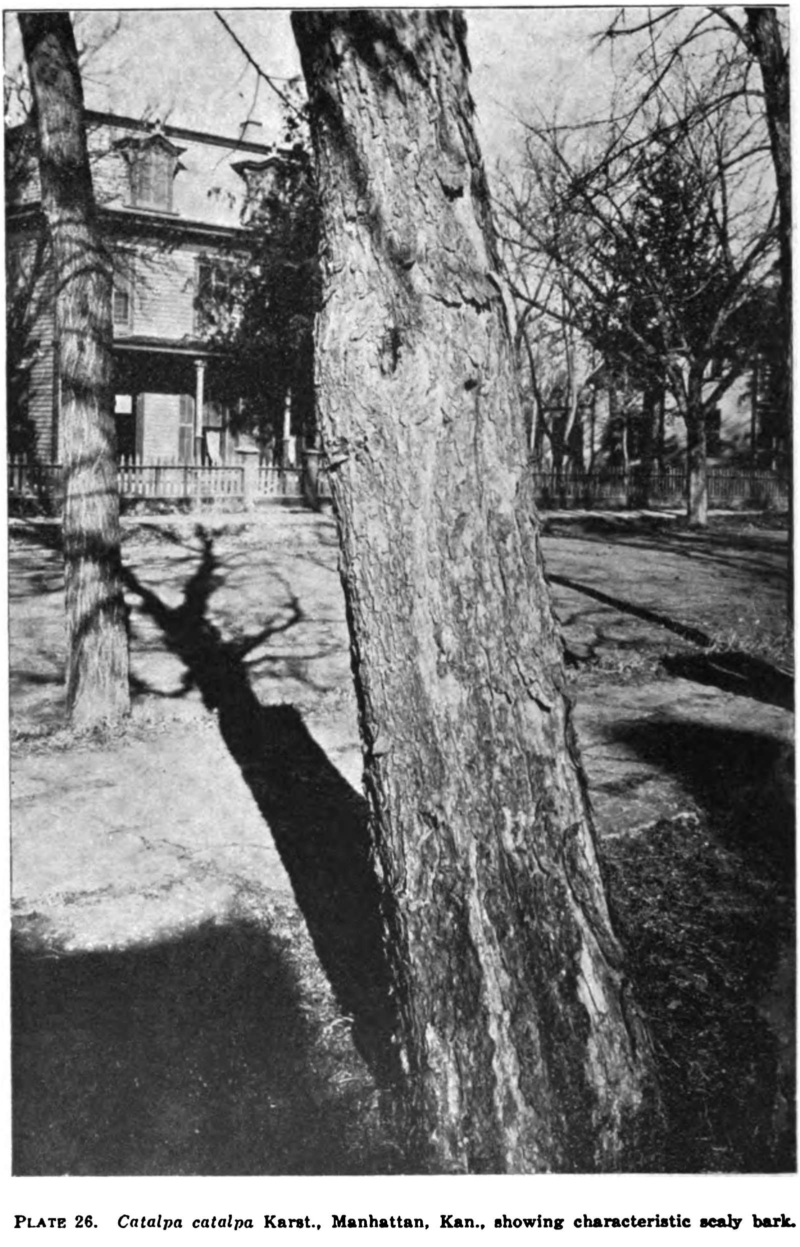


PLATE 26. *Catalpa catalpa* Karst., Manhattan, Kan., showing characteristic scaly bark.

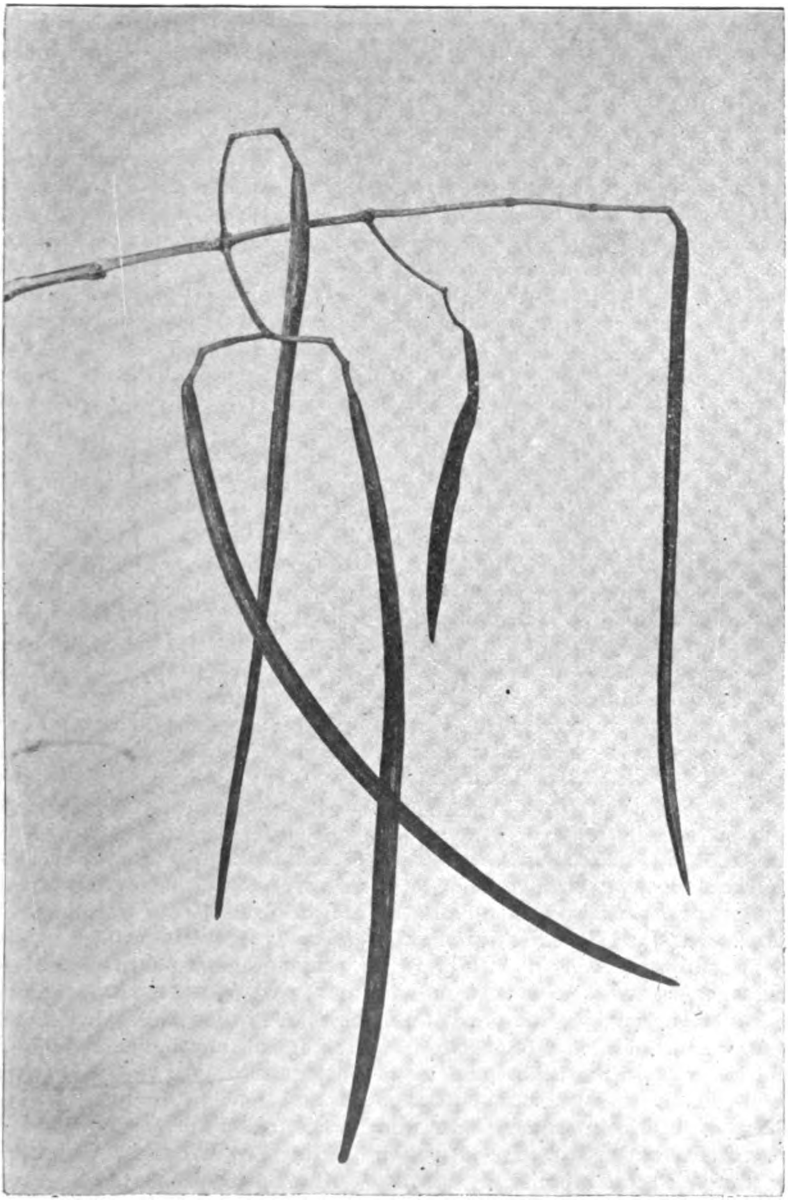


Plate 27. *Catalpa catalpa* Karst. (*C. bignonioides* Walt.) Fruiting branch, one-third natural size.

purple, and slightly puberulous. During their first winter they are thickened at the nodes, lustrous light orange color or gray-brown covered with a slight glaucous bloom, and marked with large, pale, scattered lenticels, the outer layer of the thin bark separating easily from the bright green inner layer. The leaf-scars, in which appear a circle of conspicuous fibro-vascular bundle scars, are large, oval, and elevated, and do not entirely disappear until the third or fourth year, when the branches are reddish brown, and marked with a network of thin, flat, brown ridges. The branch continues to grow throughout the summer, the end dying in the autumn, without forming a terminal bud, and appearing during the winter as a black scar by the side of the upper axillary bud. The axillary buds are minute, globose, and deeply immersed in the bark, with several pairs of chestnut-brown, broadly ovate, rounded, slightly puberulous and loosely imbricated scales; those of the inner ranks are accrescent, and when fully grown are bright green, pubescent, and sometimes two inches in length. The leaves are opposite and in threes, broadly ovate, rather abruptly contracted into slender points, or sometimes rounded at the apex, cordate at the base, and entire or often laterally lobed. When they unfold they are coated on the lower surface with a pale tomentum, and are pilose on the upper surface; and at maturity they are thin and firm, light green and glabrous above, pale and pubescent below, five or six inches long and four or five inches broad, with stout, terete petioles five or six inches in length, prominent midribs and primary veins arcuate near the margins, connected by reticulate veinlets, and furnished in their axils with clusters of dark glands. They smell disagreeably when bruised, and turn black and fall to the ground after the first frost of the autumn. The flowers, which appear from May in the South to July in New England, are produced in compact, many-flowered panicles eight or ten inches long or broad, with light green branches tinged with purple, and are borne in slender pubescent pedicels half an inch in length. The calyx is half an inch in length, and green or light purple. The corolla is white, with a broad, companulate, flat tube, and spreading limb, which, when it is expanded, is an inch and a half wide and nearly two inches long; it is marked on the inner surface on the lower side with two rows of yellow blotches following the parallel lateral ridges or folds, and in the throat and on the lower lobes of the limb with crowded conspicuous purple spots. The stamens and the style are slightly exserted. The fruit, which ripens in the autumn, hangs in thick-branched, orange-colored panicles, and remains on the trees without opening during the winter; it is six to twenty inches long, a quarter to a third of an inch thick in the middle, with a thin wall, which is bright chestnut-brown on the outside and light olive-brown and lustrous on the inside, and in the spring splits into two flat valves before finally falling; the partition is thin and light brown. The seed is about an inch long, a quarter of an inch wide, silvery gray, with pointed wings, terminating in long, pencil-shaped tufts of white hairs.

"*Catalpa catalpa* is usually supposed to be indigenous on the banks of the rivers of southwestern Georgia, western Florida, and central Alabama and Mississippi. The hardiness of this tree, however, in severe climates like that of New England, would indicate an origin in some colder and more elevated region, and it is possible that the catalpa trees which now

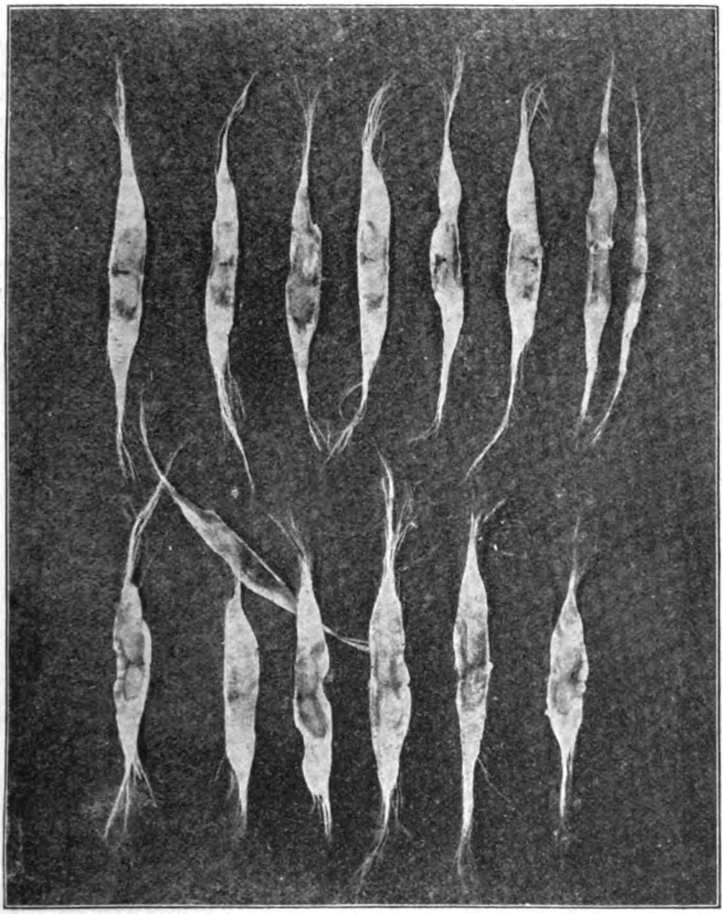


PLATE 28. *Catalpa catalpa* Karst. (*C. bignonioides* Walt.) Seeds, natural size.

appear to be growing naturally in the Southern states are the offspring of trees carried there by man.

"The wood of *Catalpa catalpa* is soft, not strong, coarse-grained, and very durable in contact with the soil, with numerous obscure medullary rays and rows of large open ducts clearly marking the layers of annual growth; it is light brown, with lighter colored, often nearly white sapwood, composed of one or two layers of annual growth. The specific gravity of the absolutely dry wood is 0.4474, a cubic foot weighing 27.88 pounds. It is used, and highly valued, for fence-posts, rails and other purposes where durable wood is needed.

"The bark, which contains tannin and an amorphous bitter principle, has been occasionally used, as well as the seeds, in decoctions for the treatment of bronchitis, and in homeopathic practice." ("The Silva of North America," Charles Sprague Sargent, vol. VI, p. 86.)

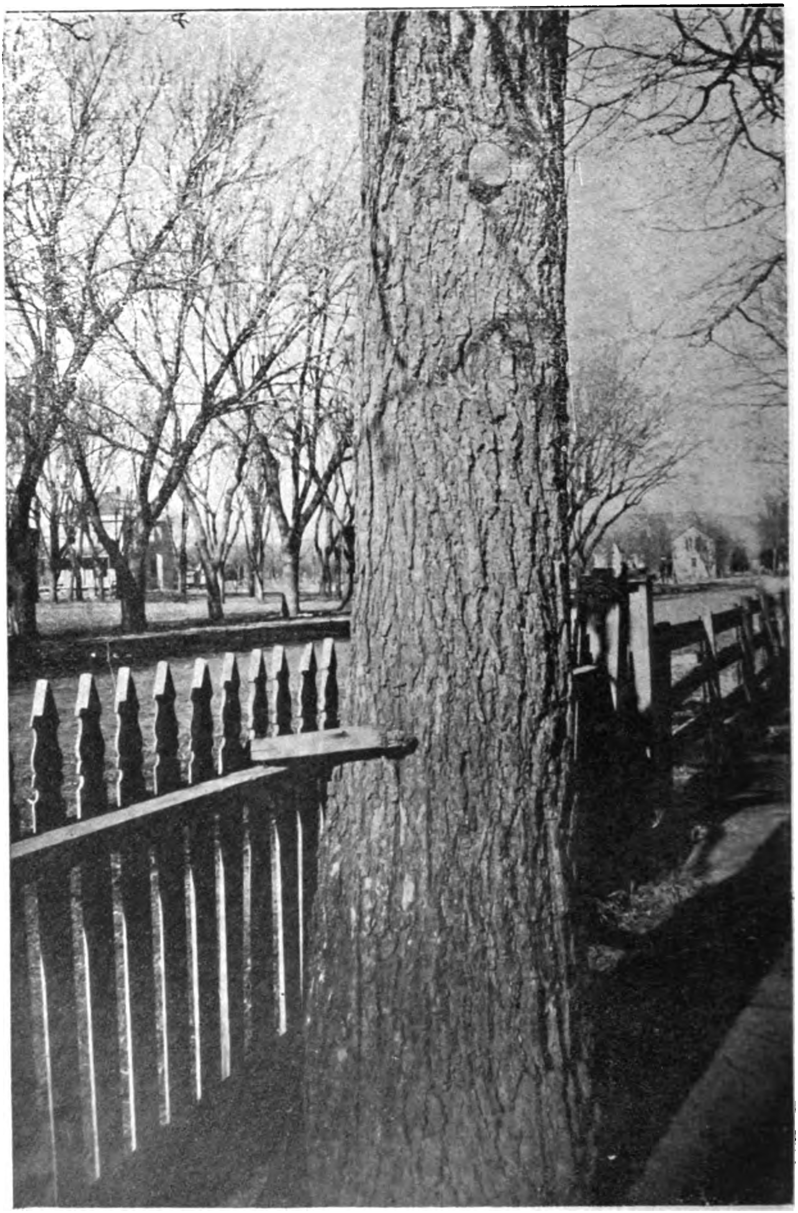


Plate 29. *Catalpa speciosa* **Ward, Manhattan, Kan., showing characteristic deeply furrowed bark, not peeling off in scales, as in plate 26.**

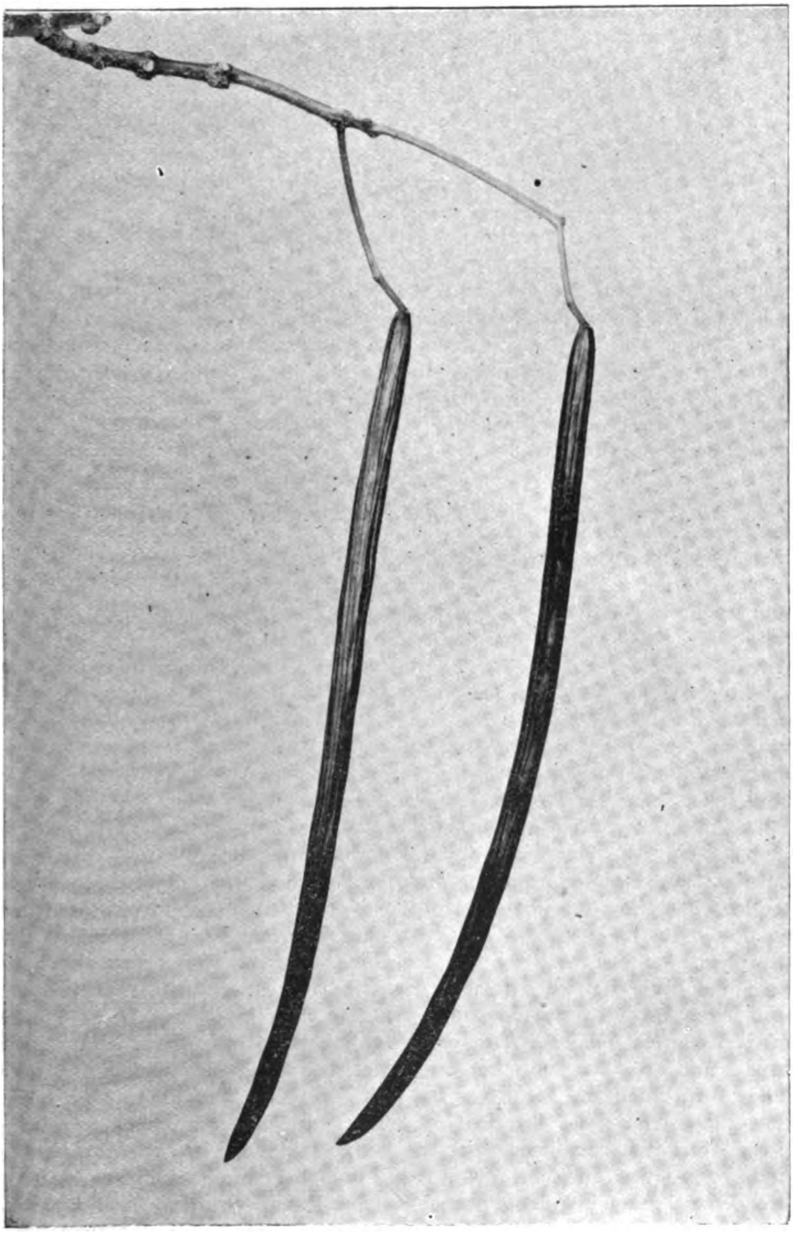


PLATE 30. *Catalpa speciosa* Ward. Fruiting branch, one-third natural size.

Catalpa speciosa Warder.

Catalpa cordifolia Jaume, in Nouveau Duhamel, II, t. 5 (1802), not Moench (1794).

Catalpa bignonioides Lesquereux, in Owen's 2d Rep. Arkan. 375 (1860), not Walter (1788).

Catalpa speciosa (Warder, in Hort.) Engelmann, in Bot. Gaz., vol V, 1 (1880).

"Flowers in few-flowered, open panicles; corolla inconspicuously spotted. Fruit stout. Leaves caudate acuminate.

"A tree in the forest occasionally 120 feet in height, with a tall, straight trunk, rarely four and a half feet in diameter, and a narrow, round-tipped crown of slender branches; usually smaller, although often a hundred feet high, and when grown in open situations rarely more than fifty feet in height, with a short trunk and a broad head of spreading branches. The bark of the trunk is three-quarters of an inch or sometimes nearly an inch thick, brown tinged with red, and broken on the surface with thick scales. The branchlets are stout, and when they first appear are light green, often tinged with purple, and covered with scattered pale hairs; during the first winter they are light orange color or reddish brown, covered with a slight bloom, and marked with many pale, conspicuous lenticels, and with the elevated oval leaf-scars, which are a quarter of an inch long and display a circular row of large fibro-vascular bundle scars; in their second and third years the branches grow darker and the leaf-scars and lenticels nearly disappear. The end of the branch dies in the autumn without forming a terminal bud, and during the winter appears as an elevated circular scar close to the upper axillary bud. The buds are minute, globose, partly immersed in the bark, and covered with loosely imbricated chestnut-brown ovate scales, keeled on the back and slightly apiculate at the apex; those of the inner ranks are accrescent and at maturity are foliaceous, obovate, acute, gradually narrowed below a sessile base, many nerved, with dark veins pubescent on the lower surface, and sometimes nearly two and a half inches long and three-quarters of an inch broad. The leaves are opposite or in threes, oval, long-pointed, cordate at the base, and usually entire or funished with one or two lateral teeth; when they unfold they are pilose on the upper surface and covered on the lower and on the petioles with pale or rufous tomentum, which soon disappears, and at maturity they are thick and firm, dark green above and pale and covered with soft pubescence below, especially along the stout midribs, and the principal veins marked in their axils with large clusters of dark glands. They are ten or twelve inches long, seven or eight inches broad, and are borne on stout terete petioles four to six inches in length. They turn black and fall after the first severe frost of the autumn. The flowers, which appear late in May or early in June, are borne on slender purple pedicels, furnished near the middle with one or three branchlets, and are produced in open, few-flowered panicles five or six inches long and broad, with green or purple branches marked with orange-colored lenticels, the lowest being often developed from the axils of small leaves. The calyx is purple and divided at the base into two ovate pointed apiculate divisions. The corolla is white, with a broad conical oblique tube nearly

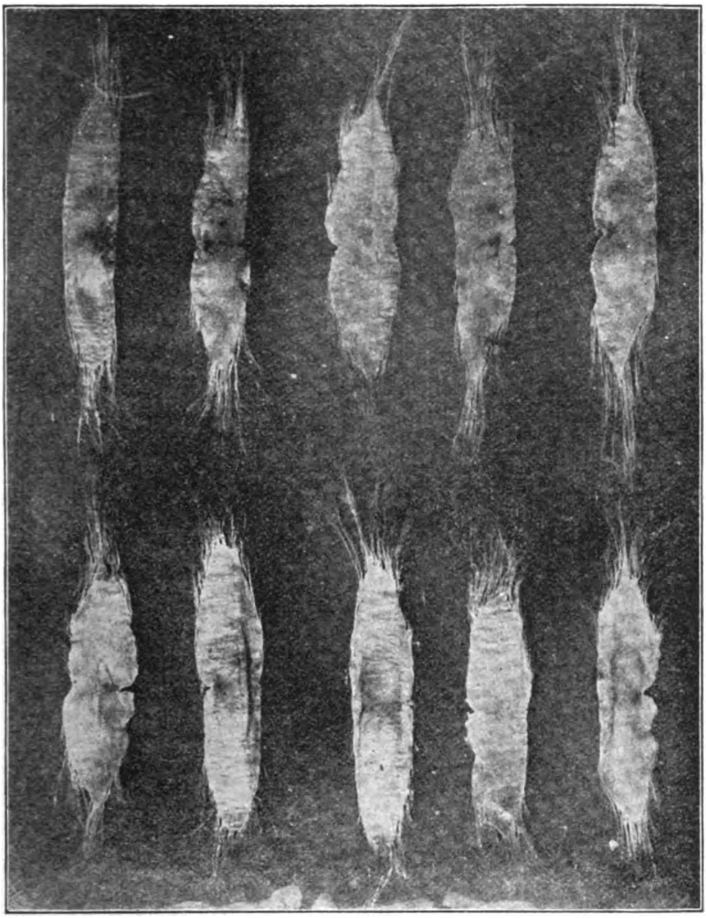


PLATE 81. *Catalpa speciosa* Ward. Seeds, natural size.

an inch long, often marked externally with purple spots near the base, and internally on the lower side with two bands of yellow blotches which follow two parallel lateral ridges, and with occasional purple spots spreading over the lobes of the lower lips of the limb, which, when the flower is fully opened, has a vertical diameter of nearly two inches and a horizontal diameter of two and a half inches. The filaments, which are marked near the base with a few oblong purple spots, are slightly exserted, and rather longer than the slender glabrous style. The fruit is eight to twenty inches long and one-half to three-quarters of an inch in the middle, with a thick wall, which towards spring splits into two concave valves; the partition is thickened in the middle and nearly triangular in section. The seed is an inch long and a third of an inch broad, with a light brown coat, and wings which are rounded at the ends and terminate in a fringe of rather short hairs.

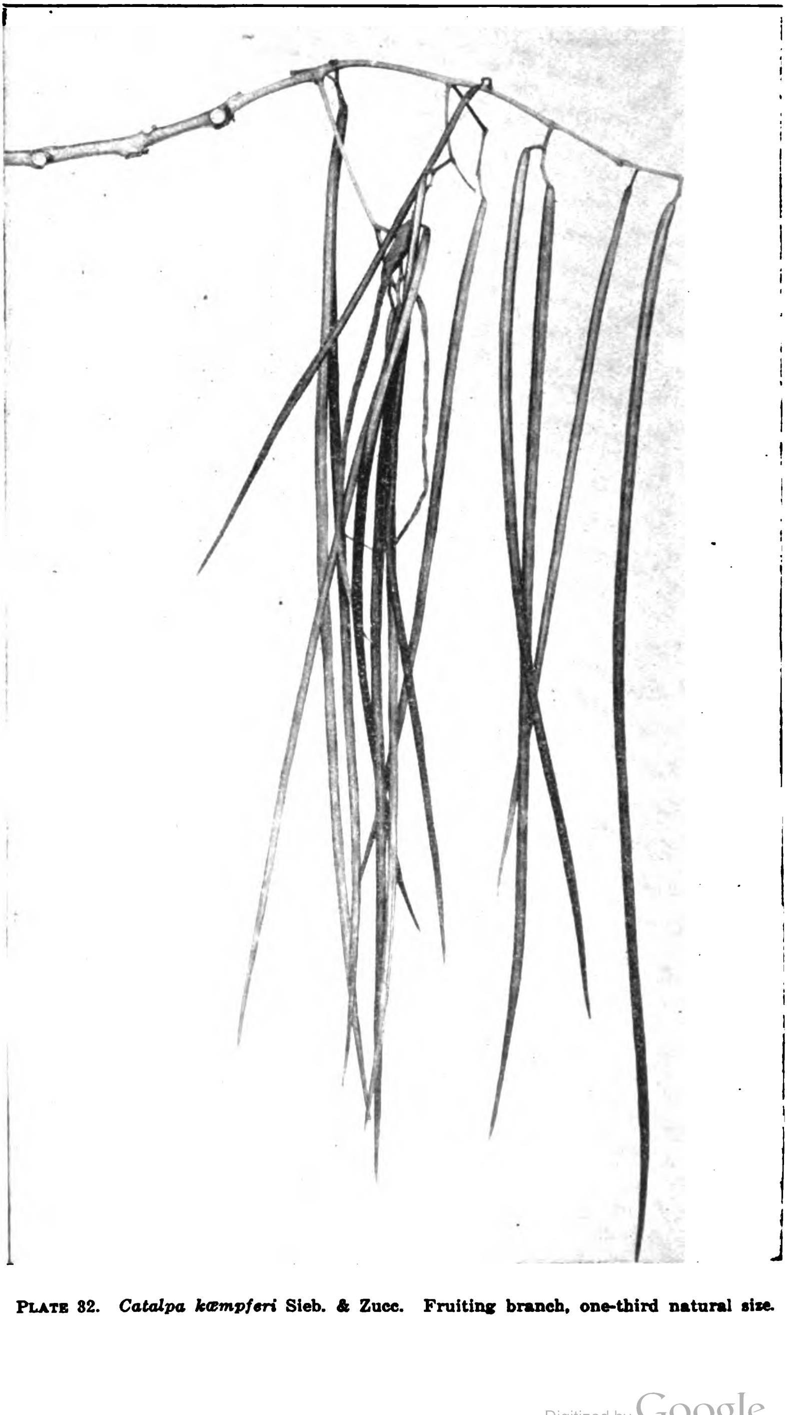


Plate 32. *Catalpa kæmpferi* Sieb. & Zucc. Fruiting branch, one-third natural size.

> "*Catalpa speciosa* inhabits the borders of streams and ponds and fertile, often undulating bottom lands, and is distributed from the valley of the Vermilion river, in Illinois, through southern Illinois and Indiana, western Kentucky and Tennessee, southeastern Missouri and northeast Arkansas; through cultivation it has become naturalized in southern Arkansas, western Louisiana, and eastern Texas. In southern Illinois and Indiana, where it probably grew to its largest size, the western catalpa was formerly extremely abundant." ("The Silva of North America," Charles Sprague Sargent, vol. VI, p. 89.)

In addition to the native species, there is quite frequently to be found in cultivation the Japanese species, *Catalpa kœmpferi* Sieb. & Zucc., in ornamental grounds, between which and the American species there appear to be numerous hybrids. The long, very narrow pods, borne in very thick clusters, and the low habit of growth, render this tree easily distinguishable. The latest botanical description of *C. kœmpferi,* published by Sir Joseph Hooker in the *Botanical Magazine,* is as follows:

> "A middle-sized tree, twenty-five to thirty feet high, with spreading, rather brittle branches and copious foliage; main branches stout; shoots green, smelling disagreeably when bruised; leaves about six inches long and broad, of a bright pale green color, with brown glandular spots at the junction of the nerves, broadly ovate, base rounded or cordate, margin sinuate or three-lobed, the lateral lobes short, terminal, tapering to a fine point, surfaces pubescent at first, then glabrous above, smooth or roughish beneath; petiole two to five inches long, round; nerve axils pubescent. Panicle terminal, erect, as long as the leaves, narrow or broad; rachis with small brown petioled leaves at the base; flowers two or three together at the ends of the branchlets of the panicle, horizontal or drooping, pale yellow, sprinkled with minute red spots within; calyx very small, lips rounded. Corolla campanulate, three-quarters of an inch long, mouth oblique, upper lip short recurved, lower spreading; lobes all rounded with crisped margins; in many of the flowers a small recurved, tongue-shaped appendage to the corolla occurs on the corolla tube near its base above. Capsule a foot long and one-third of an inch in diameter, cylindrical, straight, smooth, brown; seeds compressed, velvety, produced at each end in fine, silky hairs."

There seem to be intergrading forms between the two American species of catalpa. Whether these variants are ecological in character, assuming *C. catalpa* to be indigenous, or whether, by means of occasional early-blooming individuals of the Southeastern or occasional later-blooming individuals of the Western or hardy catalpa, hybrids have arisen between the two forms, it is on present evidence impossible to say. It is certainly true that intermediate forms exist. To the practical

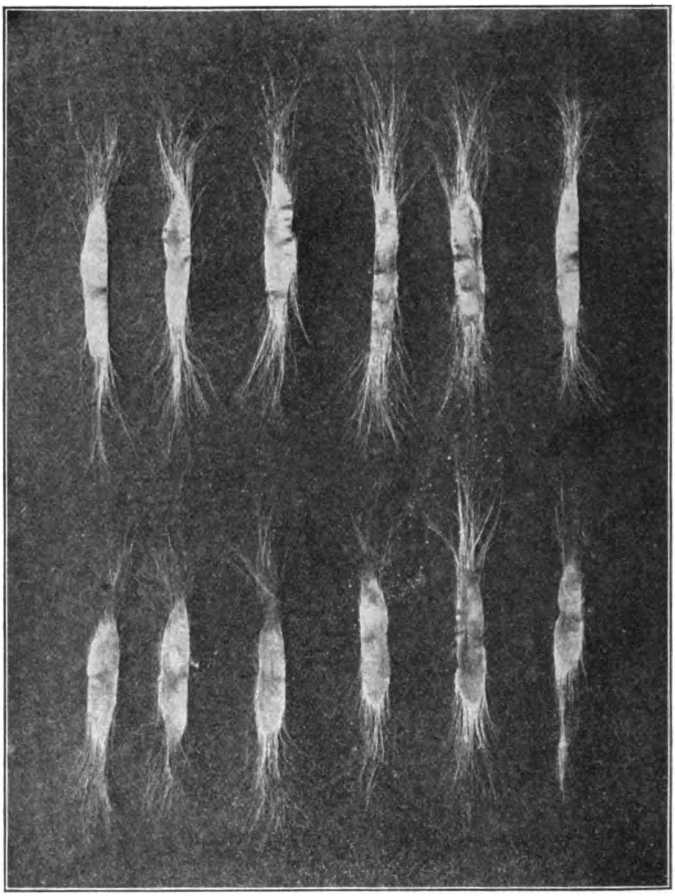


PLATE 33. *Catalpa kœmpferi* Sieb. & Zucc. Seeds, natural size. This particular tree possibly a hybrid with one of the American species.

planter the essential thing is to avoid *Catalpa kœmpferi*, *C. catalpa*, or their hybrids, or the so-called hybrids of *C. catalpa* and *C. speciosa*, and so far as possible to confine his forest to trees most near to the best type of *Catalpa speciosa.* Great carelessness is said to exist in the trade in the matter of distributing pure seed of *C. speciosa.* For the benefit of prospective catalpa growers without special botanical knowledge, a few salient characters may be seized upon to distinguish the species in question. In the first place, the fact that *C. speciosa* blooms about two weeks earlier than *C. catalpa*, bears larger and showier flowers, fewer in cluster, will usually be a safe distinguishing feature. It cannot be too strongly urged upon catalpa planters *to grow their own trees from seed.* By this means the danger of obtaining the undesirable species is greatly lessened, since careful study of the seed characters offers an additional safeguard. If the prospective grower gathers his own seed, it will be well to obtain it from mature trees, if possible, since the bark characters offer striking contrasts in the two species. The bark of *C. catalpa* is scaly, peeling off in short strips, much as does that of the wild cherry. *Catalpa speciosa,* on the other hand, like the ash or the box elder, has furrowed bark, not separating from the trunk in scales. Plates 29 and 30 show quite well these contrasting characters. While the pods of the hardy catalpa are usually longer, larger and straighter than those of the Southeastern species, this is not an invariable rule. The seeds of *Catalpa speciosa,* however, are quite readily distinguished from those of *C. catalpa,* in the fact that they are wider, have usually a more pronounced notch between the wings, and the tips of the latter are fringed with a brush of hairs which stand squarely out from the wings and are not drawn into narrow points (plates 34 and 35). *Catalpa kœmpferi* and its hybrids have the hairs on the seeds arranged much as in *C. speciosa,* but the seeds themselves are so much smaller and narrower that no confusion is possible (plate 36).

CATALPA PLANTATIONS AT THE AGRICULTURAL COLLEGE.

The earliest planting of catalpa by the Agricultural College was made in 1872. The trees were a part of a mixed planting made on the old College farm. Prof. E. Gale, in a report made to the State Board of Agriculture, and published as a part of the Transactions of the State Board of Agriculture, 1872, page 430, says in regard to the soil: "The land selected for this purpose was that least adapted to the cultivation of cereals or root crops of any now broken up on the College farm. This selection, all things considered, was thought best, for it is, in general, this quality of soil—the high, gravelly and broken ridges—which should ultimately be planted to forest." Speaking of the planting as a whole, he says: "As was anticipated, the growth of the young trees has not been as vigorous upon this soil as it would have been upon lower and richer land, but still abundantly sufficient to give the most encouraging promise of future success." Speaking of the growth of the catalpa, in this planting, he says: "The catalpa has made a growth of from twelve to twenty inches from seed."

In part II of the Fifth Biennial Report of the State Board of Agriculture, 1885-'86, page 159, in "Notes from the Experimental Tree Planting at the Agricultural College," Prof. E. A. Popenoe says regarding the catalpas planted in 1872: "*Catalpa speciosa.* On poor gravelly clay soil, planted much more closely than the white ash, not thinned, excepting by the removel here and there of trees for posts. Stand about twenty-five feet in height, and have an average circumference of about fifteen inches; the largest trees twenty-two inches at four feet from the ground. Trunks more likely to fork or carry large branches below than those of white ash."

It will be noted from the foregoing quotations that the catalpas, even on this exceedingly poor soil, were being cut for posts when not more than thirteen years from planting. Having been planted so long before the establishment of the Experiment Station, accurate records are wanting. Some posts have been cut nearly every season; in 1901 sixty-five were cut from this planting. It is evident from the information available that the ground has paid as high a rental as good land has paid in farm crops. The trees have not renewed from sprouts as readily as have the trees on lower, richer land, but have done fairly well in this respect. At this date, November, 1901, nearly thirty years from planting, and with good rent for the past sixteen years, this plat of ground of about three-fourths of an acre contains 350 trees, which would cut at least 610 good posts. This does not represent all the value of this planting, for the soil is evidently very much better than when the trees were planted. The leaves have given texture to the soil, which now shows some considerable humus in its composition. The ground is now practically under forest conditions, and seedlings of box elder, mulberry, elm, ash, oak and red cedar are found growing among the catalpas. Plate I shows one of the best of the trees now growing in this planting; it is twelve inches in diameter and over thirty-five feet high. Some idea of the growth of underbrush and young trees may be had from the same plate.

In the spring of 1888 the horticultural department of the Experiment Station planted about two and sixth-tenths acres of the old College farm to catalpas. The soil of this plat, while not so decidedly poor as that of the planting of 1872, is very thin, and is underlaid by a hard, poor subsoil. Plantings were made four feet by two feet, four feet by four feet, and four feet by eight feet. All were given good, clean cultivation for two years. The third season the trees set eight feet by four feet were cultivated; those set closer were large enough to make cultivation difficult. The ground was well shaded and fairly well covered with leaves, so the lack of cultivation did not seem to affect their growth. Each season the trees were trimmed to prevent their branching too low for the formation of good posts. Results show that the time required for trimming was well spent.

In the rows set four feet by two feet, many of the trees died or were cut out within a few years after planting, before the wood was of any value. Subsequent thinnings gave wood and stakes enough to pay for the work. This planting, for the last eight or nine years, has been practically a four-by-four-foot planting. The trees which were removed seemed to have little effect in causing a taller, straighter growth, the trees in the four-feet-by-two-feet block showing little difference in height and somewhat less in diameter; in other words, the additional trees were of no benefit, but, on the contrary, were a detriment. In a part of this planting where the trees had been left at the original distances until 1900, the trees in one of the four-foot rows had more than twice the amount of posts and wood as the trees two feet apart.

Comparing the plantings originally 4 x 4 and 4 x 8, the thinner plantings have given the best results. Ten rows, 4 x 4 feet, 117 feet long, contained 251 trees having 85 good posts. Ten rows, 8 x 4 feet, 117 feet long, grew 228 trees, having 280 good posts. The trees in the wider rows have a greater height and diameter, the average diameter in the planting 4 x 8 feet apart being slightly under six inches; in the rows, 4 x 4 feet apart the average diameter is nearly four and one-fourth inches. The average height is about the same, eighteen feet.

In some cases, where trees were thinned by cutting off just above the ground, the new shoot from the stump made such a straight, rapid growth that the cutting back seemed to secure the formation of straighter posts. As might be expected, the second-growth posts grow to a suitable size for use in less

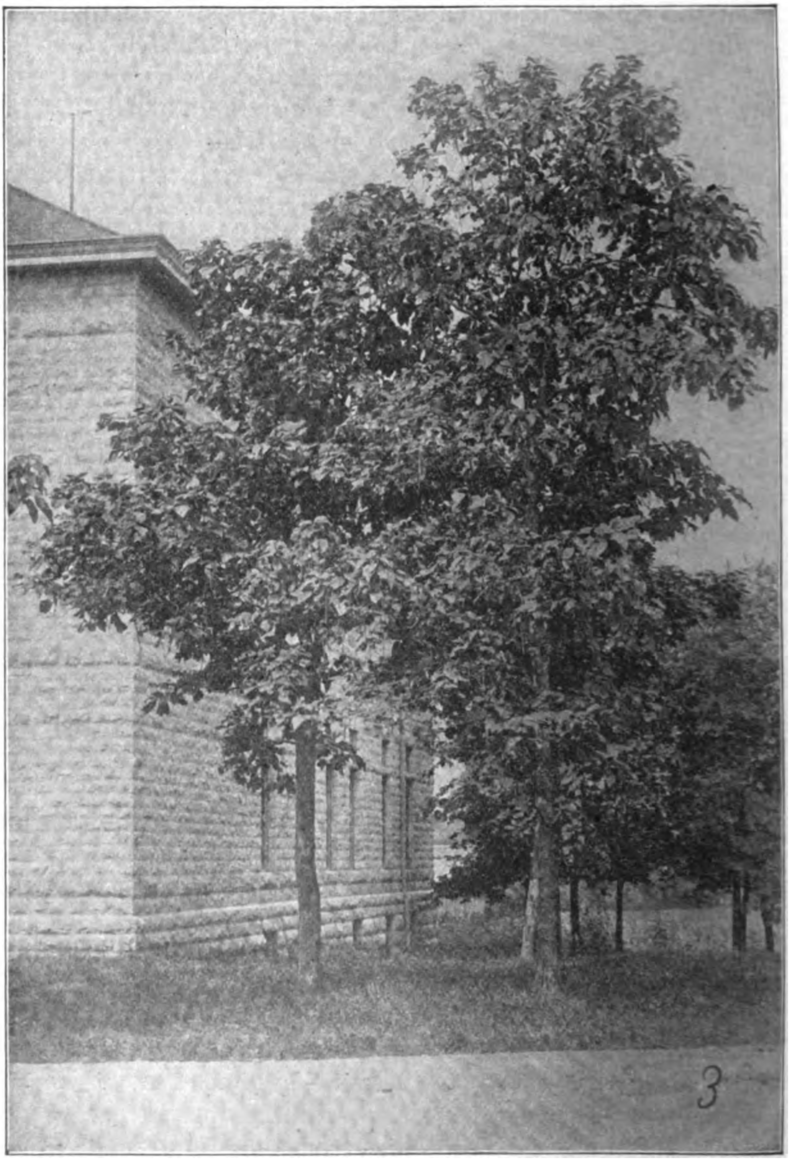


Plate 34. Catalpas used for shade trees at Agricultural College.

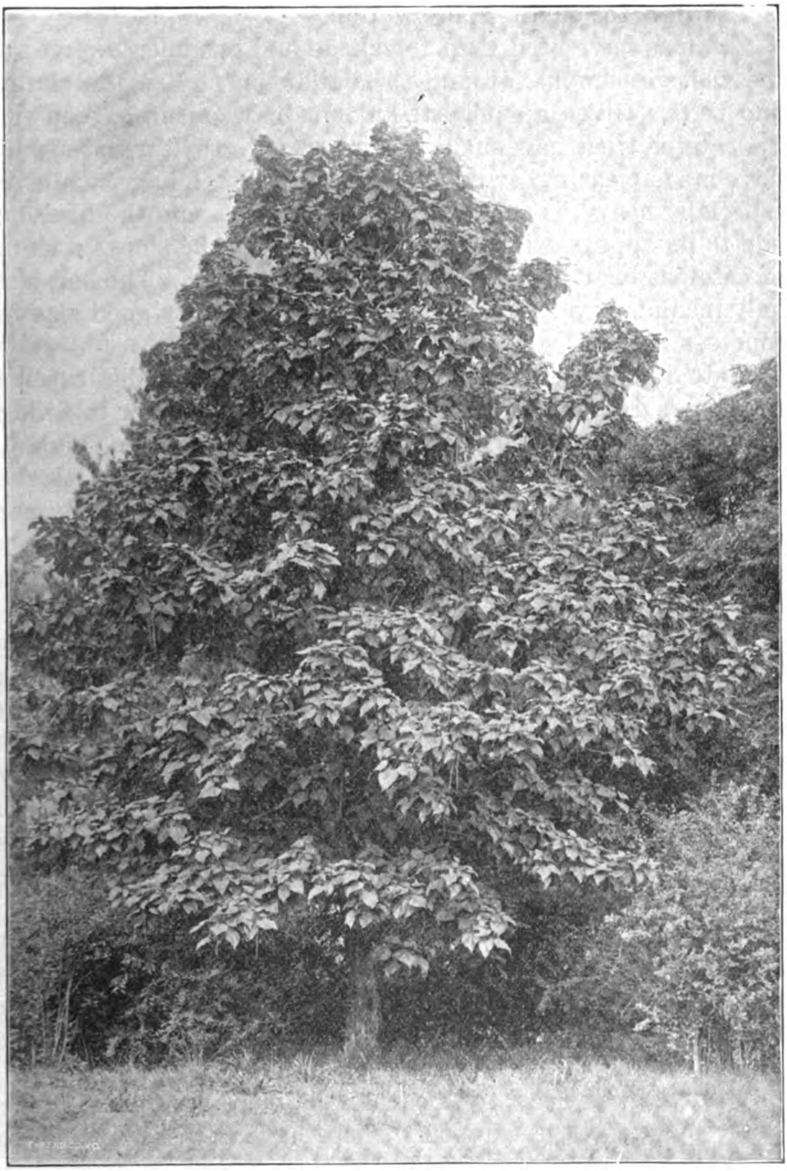


Plate 35. Golden catalpa on Agricultural College campus.

time than was required for the first growth of trees. The comparative value of the first and the second growths for posts is a subject for further observation.

Catalpas have been used for shade and ornamental trees on the College campus, around the buildings, and in the clumps and belts. Given a sufficient amount of room, in a good soil, the catalpa trees have made a fairly rapid growth, and usually have made pleasing, symmetrical form. The foliage, while not especially heavy, is sufficient for good shade, and the blossoms add to its appearance in their season. Plate 34 shows a clump of catalpas near the Domestic Science building. The soil is of only medium quality, and the trees are of a very good size for fourteen seasons' growth.

Plate 35 shows a very fine specimen of the Golden catalpa; the tree is graceful and symmetrical, rather heavier in foliage than most of the trees of this species. It is 36½ feet high, 15 inches in diameter at two feet from the ground, and 13½ inches at four feet from the ground. The yellow tint is quite conspicuous in the early part of the season, but is much less so after midsummer. Young trees show the yellow shade much more than the older ones.

Specimens of the Purple-leaved catalpa have been grown on the College campus. The purple tint is much more conspicuous in the younger trees, and with these the colors are most vivid in the early part of the season. The specimens grown here have been grown on a soil of medium quality, and have made but a moderate growth, inclining to be shrubby. Probably the best results in the way of foliage would be secured by cutting back severely and growing as shrubs.

The Japanese catalpa, *Catalpa kæmpferi*, has made rather a low, shrubby growth on the College campus. It presents a fine appearance when in bloom, carrying a heavy load of flowers. In the fall, after the leaves are fallen, it presents a rather unique appearance, the large number of slender pods giving the branches a drooping effect.

A number of Teas' hybrid catalpas were set in the timber belts on the College campus. These have been somewhat variable in form and growth, but have, on the whole, made good growths and fine trees.

Some of the trees set in a coöperative experiment with the division of forestry, Department of Agriculture, are evidently of the Southern species, *Catalpa catalpa.* They were killed to the ground in February, 1899, and have been seriously injured by cold in other seasons. Doubtless much of the dissatisfaction with the catalpa has been caused by the setting of other species than *speciosa.*

Posts set ten years ago in the Experiment Station vineyard are still in very good condition, and there is no doubt that they merit the general favor in which they are held. The wood not suitable for posts makes very fair fuel. It burns readily and lasts well for so light a wood. Plate 36 shows the cross-section of a catalpa planted in 1880 and cut in 1900. Plate 37 shows the section of a board cut from the same tree. The trunk made a board eight feet in length, the width of that shown in the plate. When cut, this was a fine, healthy tree, with a spread of at least twenty-five feet. The best development of the belt in which it grew demanded its removal.

Trees of suitable size for sawing have been used by the mechanical department for various purposes. Mr. W. L. House, foreman of the College wood-working shops, says in regard to the catalpa wood: "It has a beautiful grain, polishes easily, and takes a fine finish. It has sufficient strength for the various kinds of cabinet work, and is desirable in every way for this purpose. For wide surfaces it joins nicely, matching the grain easily. It works easily, either with the lathe or with hand tools, and is, in every respect, a valuable wood for the finisher and cabinet-maker."

Nursery Notes.

Seedlings of the catalpa are easily grown. No difference has been noted in the vitality of seed gathered in the fall and stored in a dry, cool place and in that which had hung on the trees until spring. Good stands have been secured by planting in rows of suitable width for cultivation, dropping the seeds quite thickly in the row and covering rather shallowly, about one inch deep. Plantings made when the ground is in good, warm condition have succeeded better than plantings made very early or very late. On good soil and with good care, the growth of catalpa seedlings has been from one to five feet the first season. One-year-old trees are best for planting. In the planting of 1888, yearling trees have made posts as soon as two-year-old trees. The yearling trees are easily set by laying off the rows with a plow or lister, followed by a little work with the spade, care being taken to firm the soil well when the tree is put in position. Setting in the spring is usually most successful, and should be done before the buds are much swollen. As with all trees that are being transplanted, care must be taken to prevent drying. If the roots be exposed for only a few minutes to the sun or drying winds, the chances for success may be seriously reduced.

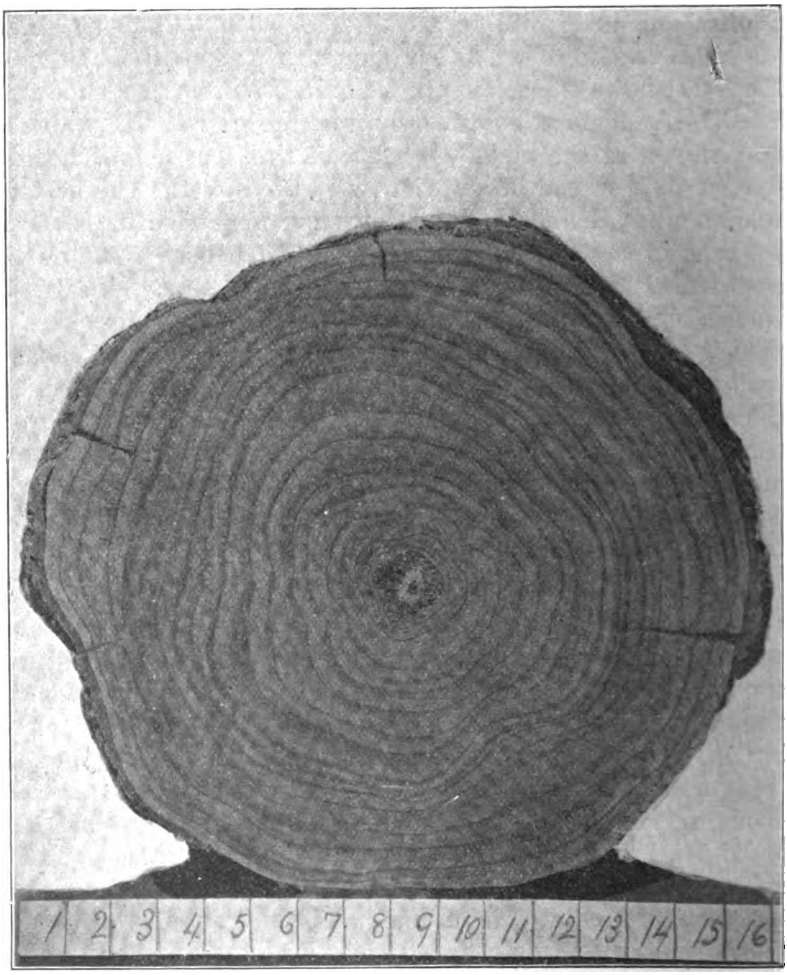


PLATE 86. Cross section of catalpa grown on Agricultural College campus.

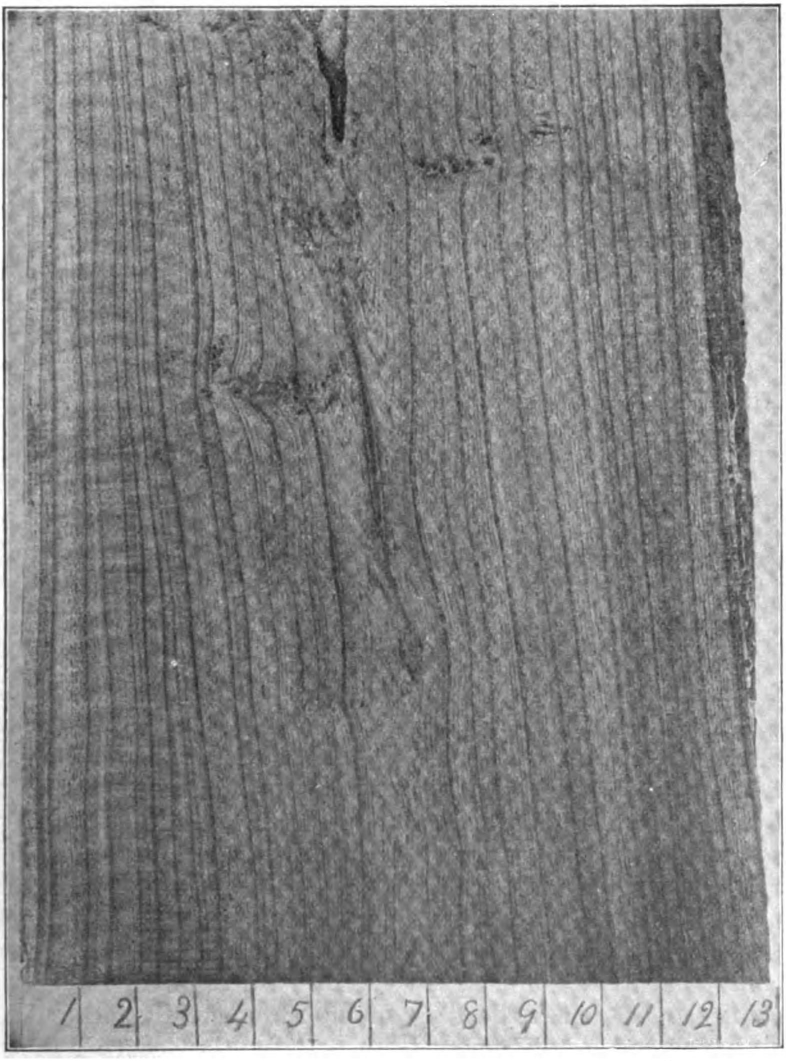


PLATE 37. Section of board from catalpa tree grown on Agricultural College campus.

Conclusions.

The catalpa plantings made by the College and the Experiment Station have given encouraging results. On very poor soil the catalpas have been a paying crop. Almost any other cropping of this land would have reduced its fertility, while the crop of trees has unquestionably been beneficial, both by preventing washing and by the addition of some humus.

On good soil the growth has been proportionately better. The trees have made a more rapid and vigorous growth, producing trunks of suitable size for posts in from seven to ten years, and in twenty years trees have grown to a size sufficient for heavier uses, or for lumber for finishing or cabinet work.

The most desirable distances for planting probably vary somewhat for different soils and locations. Rows eight feet apart, with the trees five or six feet apart in the row, would seem, from our observations, to be a good distance for general planting. With the rows eight feet apart, corn or some other rowed crop may be planted for at least one season.

Good clean cultivation should be given for several years. Attention should be given to trimming the trees, to avoid low branching.

Cutting back to the ground usually secures a rapid growth of smooth straight wood.

The young trees are easily raised, transplant readily, grow rapidly, and endure extremes of drought, heat, and cold.

PRESENT WORK AT THE DODGE AND OGALLAH FOREST STATIONS.

In addition to the work incident to the collection of data concerning the natural and artificial forest resources and possibilities of Kansas, the Stations at Dodge City and Ogallah have been maintained. Their equipment has been increased by the purchase of teams and implements and the plantings of forest trees put into condition to prevent any future injury from fire and to enable them to make the best of the conditions under which they are growing. In other words, the purpose now is to give these trees, that are expected to furnish encouragement and object lessons for future planters, a fair chance and a "square deal" by maintaining effective fire guards and such soil conditions as seem best for the securing of the forest conditions under which they may succeed. The breaking up of the sod has been the first requisite, and in future the conditions needed for the conservation of soil and moisture will be maintained so far as is possible.

Plantings of shade-enduring species will be undertaken where the trees are too few to furnish shade for the protection of soil and stem. Species which have demonstrated their ability to succeed will be most used and in numbers which will furnish a basis for accurate estimates of their rates of growth and their general value.

Demonstrations in other agricultural lines authorized by the legislature have been begun. The possibility of preparing soil for trees by the use of preceding crops is the main object undertaken, but the value of the cowpea in furnishing a protein feed for localities where other legumes have not been introduced was incidental to its use in preparing soil for tree purposes. A comparison of the value of milo maize, both dwarf and standard varieties, with the Kafir corns, was begun and will be continued.

The season was less favorable at the Dodge City Station, but good crops of fodders were obtained. Demonstrations of the value of improved seed wheat are also under way on land not yet required for the work with trees.

The wholesale distribution of seedlings undertaken by these Stations in the past has not been productive of the good intended. The evil of setting poorly handled trees in poorly prepared soil has been discussed in this report, and it is not proposed to continue this evil. The nursery efforts will be in the direction of ascertaining means of producing trees which are best adapted to western Kansas conditions and ascertaining the added value and the feasibility of the planting by general farmers of seeds where the trees are to stand.

Trees grown by these Stations will be used in demonstrations made in coöperation with individuals, school districts, counties and towns, and careful investigation will be made as to the preparation of the soil and adaptation of trees for the several locations.

It is the hope of the State Experiment Station that through the office of state forester the facts concerning tree growth and the probabilities of success with the various species may be so widely disseminated that a much greater degree of success may attend future efforts in tree planting. It is certain the proper preparation of soil and correct selection of species should precede any planting.

There are many localities, particularly in central Kansas, where plantations for post and pole purposes are as nearly certain to produce very good profits as are any agricultural investments. The office of state forester will attempt to advise prospective planters concerning the adaptation of species to soils and locations and as to the best methods of soil preparation. When possible, planting plans will be prepared showing the details of distance and proportion of species. It is not considered advisable to undertake to make plans for areas smaller than two acres, but all possible advice and help will be given regardless of the area under consideration. Advice concerning public grounds will be undertaken and plans prepared for the planting of trees for school grounds. It is believed that many districts in the state can well afford to add a few acres to the school grounds for the planting of a demonstration wood lot. This should be particularly true of districts where consolidated schools are maintained. An acquaintance with trees, their requirements and their values, is an essential part of a well balanced education and furnishes a means of mental growth as well as a fund of useful information.

A grove of well-grown trees is a valuable possession for any municipality, providing a location for public gatherings and adding in many ways to the comforts and amenities of life in country and town. Such a plantation has a financial as well as a landscape value, and in years to come a grove of good timber will be a valuable resource for any owner.

In or near many towns there are areas of varying size, ravines or low land, that are now unsightly spots but which might be transformed into bits of woodland that would add charm to the landscape and in time to the wealth of the community.

On many farms there are ravines forming along the lines of drainage that if planted to trees might produce posts, poles and fuel for the farm and at the same time check the force of the water and lessen the amount of good soil that washes down the creek to increase the delta of the Mississippi and the expense of the deep waterway project. Good citizenship should demand that the owner of land protect it, conserve and increase its resources, as he would have the state and the nation protect and improve the public domain. To help in this work of making Kansas utilize all of her acres to the best possible purpose, to make the ravines, hillsides and bends of the streams produce crops for which they are best suited and by which they may add to the wealth and welfare of their owners and the state, is the object of the office of state forester.

Acknowledgment is due Mr. H. C. Cooper, who was in charge of the Dodge City Station until July, 1909, for his effective work in improving the conditions at that Station; to Mr. F. J. Turner, who, as foreman of the Ogallah Station, has done very efficient work in improving the conditions for the tree plantations there, and in carrying out the directions for the demonstration work. Acknowledgment is also due Assistant Christian Jensen, who has been in charge of the Dodge City Station since July, 1909, for very efficient service in the management of that Station, and also in the collection of data concerning tree growth in western Kansas, and in preparing plans for various courthouse plantings and for the Reformatory at Hutchinson.

Sci 1633.55

Kansas State Agricultural College.

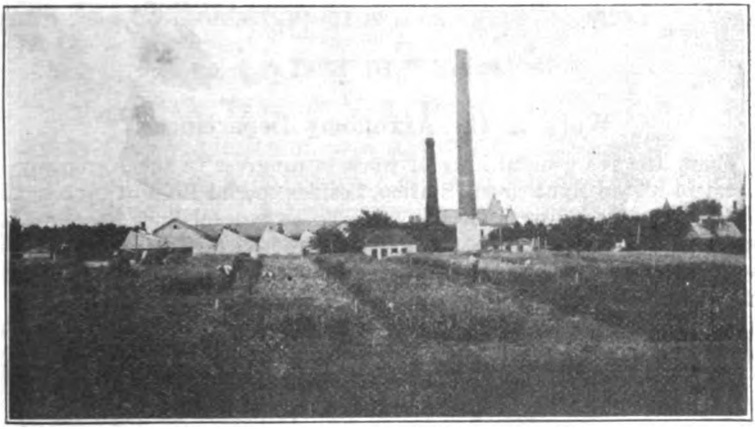
EXPERIMENT STATION.—Bulletin 166.

Ed. H. Webster, *Director.*

FARM BULLETIN.

Agronomy Department.

A. M. TenEyck, *Agronomist in Charge.*



General View, Head-row Breeding Plots.

SPRING GRAINS.

BY

A. M. TenEyck, *Agronomist.*

MANHATTAN, KAN.
March 24, 1910.

Kansas State Agricultural College Experiment Station.

AGRONOMY DEPARTMENT.

ALBERT M. TENEYCK	Agronomist in Charge.
LELAND E. CALL	Assistant in Soils.
————————	Assistant in Crops.
CLARENCE W. NASH	Assistant in Crops.
CHARLES J. T. DORYLAND	Assistant in Soils.
CARL F. CHASE	Assistant in Farm Mechanics.
FLOYD HOWARD	Farm Foreman.

Work of the Agronomy Department.

There are five general lines of work in progress in the Agronomy Department of the Experiment Station, besides special lines of investigation that are taken up from time to time. These general lines are: (1) Variety testing and improvement by selection of all farm crops; (2) planting and cultural tests to determine the best time and method of planting and best methods of preparing the soil and cultivation; (3) soil-fertility experiments, including physical investigation of the soil; (4) harvesting, curing and storing all kinds of farm crops; (5) investigations of the various lines and kinds of farm machinery.

Bulletins are issued from time to time on these subjects, which, with bulletins from other departments of the Station, may be obtained, free of charge, by addressing the Director, Experiment Station, Manhattan, Kan.

Other Departments of the Station Are—

ANIMAL HUSBANDRY	ROLAND J. KINZER in charge.
BOTANY	HERBERT F. ROBERTS in charge.
BACTERIOLOGY	WALTER E. KING in charge.
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SPRING GRAINS.

The first step in crop improvement is the testing of varieties. Different varieties of the same kind of grain when grown under similar conditions vary greatly in hardiness, yield and quality of product. Of the several hundred varieties of wheat, oats, barley and other small grains which have been grown in comparative trial plots at the Kansas Experiment Station during the last seven years, only a few varieties in each class have proven superior in all essential points so that they may be recommended for general planting in the state. Adaptation is the factor which finally determines whether a grain may be successfully grown in a given locality.

I.—Test of Varieties.

A TEST OF VARIETIES OF OATS.

Forty-four varieties of oats have been tested at this Station during the past seven years. Most of these were grown but two or three years and discarded because of their inferiority. A number have been grown continuously for five or seven years. The yields and other data for thirteen of the best varieties are given in table I.

The table shows that only four of the thirteen varieties proved of sufficient value to be generally recommended for planting in this state—the Red Texas, Sixty-day, Kherson, and Burt. Such varieties as the Minnesota No. 202, Silvermine, Early Champion, White Russian and Swedish Select may be grown with more or less success in the northeastern counties of the state, but even in these counties the Kherson should be the preferred variety, since it has also proven to be one of the best producing varieties at the Nebraska and Iowa experiment stations.

Description and Adaptation of Varieties.

IMPROVED RED TEXAS. This is the highest yielder, average for seven years being 44.03 bushels per acre. It is best adapted for growing in the central, south-central and southeastern portions of the state.

TABLE I. A comparison of varieties of oats tested at the State Experiment Station at Manhattan, Kan., arranged in order of average yield for five years.

Bulletin No.	VARIETY.	Type of seed.	Average for 1907-'08-'09			Yield per acre, 1909	Yield per acre, 1908	Yield per acre, 1907	Av. yield per acre, 1908-'09, two years	Av. yield per acre, 1907-'08-'09, three years	Av. yield per acre, 1905-'09, five years	Av. yield per acre, 1903-'09, seven years
			Height of straw	No. of days to mature.	Weight per bushel							
			ins.		*lbs.*	*bus.*	*bus.*	*bus.*	*bus.*	*bus.*	*bus.*	*bus.*
36	Improved Red Texas	Large red	38.0	107	27.90	63.72	37.50	45.23	50.61	48.81	51.01	44.03
1	Sixty-day	Small yellow	36.3	104	24.25	69.67	23.60	41.33	46.63	44.86	45.82	43.98
8	Kherson	Small yellow	35.0	103	25.50	60.45	28.70	39.94	44.57	43.03	44.72	42.50
3	Minnesota 202	White	46.0	115	26.00	55.99	19.50	44.91	37.74	40.13	42.71	36.46
21	Burt	Medium red	33.0	108	*24.00	64.85	41.90	27.37	53.37	44.70	41.39	....
15	Silvermine	Medium white	39.0	112	24.80	55.68	9.18	22.62	32.43	29.16	38.37	34.10
30	White Tartar	White	44.6	117	23.80	38.65	6.20	37.45	22.42	27.43	37.22	....
35	Stavropol	White	45.6	114	27.00	55.83	13.31	28.60	34.57	32.58	36.81	....
37	White Russian	White	42.6	114	26.10	50.74	11.40	30.82	31.07	30.99	34.89	①32.05
5	Tartarian	White	46.0	116	26.30	53.64	7.01	29.16	30.32	29.94	34.12	31.37
25	Swedish Select	White	37.6	111	25.60	52.82	12.49	8.14	32.65	24.48	32.75	....
22	Irish Victor	Large white	40.6	110	24.30	45.53	8.10	22.64	26.81	25.42	32.72	29.67
14	Early Champion	White	*38.0	*105	*22 25	....	15.50	20.81	....	*18.15	*26.29	*26.69

* 1909 crop not included.
①. 1903 crop not included.

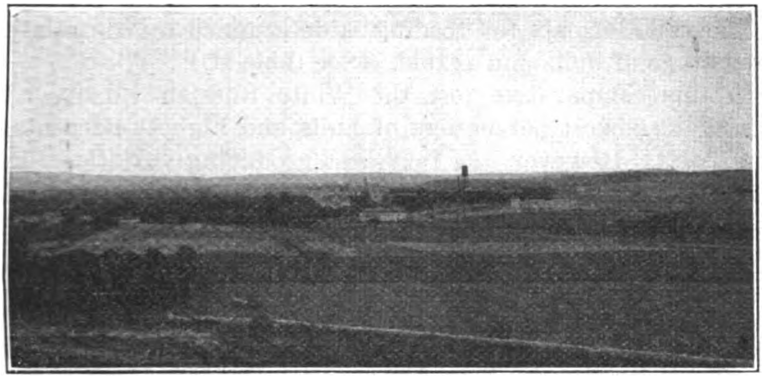

PLATE I. General view of experimental field plots, with College buildings in background.

SIXTY-DAY. Ranks second in yield, and for seven years averaged 43.93 bushels per acre; a hardy variety and good drouth resister. Recommended for western Kansas.

KHERSON. Ranks third in yield for seven years, averaging 42.5 bushels per acre; reported as the best producing variety in Nebraska and Iowa, and well adapted for northern and northeastern Kansas.

BURT. One of the earliest maturing varieties, average yield for five years being 41.39 bushels per acre; very hardy and a drouth resister. Recommended for western Kansas.

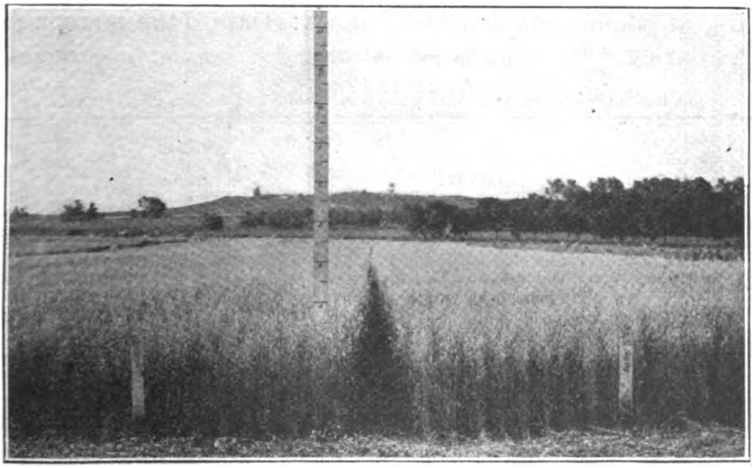

PLATE II. A comparative test of oats in one-tenth-acre plots.

Relative Value of Different Varieties of Oats for Feeding.

The value of oats for feeding is determined by the relative percentage of hulls and kernel. (See table II.)

In this comparative test the White Russian variety contained the lowest percentage of hulls and highest percentage of kernels. However, the four best producing varieties—Red Texas, Kherson, Sixty-day, and Burt—also contained a relatively high percentage of kernels, which indicates relatively high feeding value. The hardiness and productiveness of these varieties make them the more profitable ones for growing in this state.

A TEST OF VARIETIES OF BARLEY.

Thirty-two varieties of spring barley have been tested in trial plots at this Station during the past seven years. The yields and other data for ten of the best producing varieties is given in table III. For comparison the yields of spring wheat, spring and winter emmer, winter rye, winter wheat and winter barley are also given in table III.

The Mansury six-row bearded barley ranks above all other varieties in yield. The Hulless barley has been an inferior yielder, while the Beardless variety has not produced as high a yield or as good a quality of grain as the better producing bearded varieties. Comparing the yields of the highest producing varieties of oats and barley, it is seen that the barley has outyielded the oats. The average annual yields for seven years, in pounds, compare as follows: Oats, 1409 pounds per acre; barley, 1666 pounds per acre.

TABLE II. Comparison of husk and kernel in oats and emmer, crop of 1909.

Bulletin No.	VARIETY.	Weight of grains in grams.	Per cent of meat or kernel.	Per cent hulls.
36	Red Texas	1.979	74.27	25.73
1	Sixty-day	1.098	73.28	26.72
8	Kherson	1.272	73.89	26.11
3	Minnesota	1.319	73.54	26.46
21	Burt	1.406	75.24	24.76
15	Silvermine	1.462	69.90	30.10
30	White Tartar	1.348	71.73	28.27
35	Stavropol	1.815	74.14	25.86
37	White Russian	1.482	78.94	21.06
5	Tartarian	1.235	72.76	27.24
25	Swedish Select	1.703	71.05	28.95
22	Irish Victor	1.277	73.21	26.79
......	Emmer	2.466	75.22	24.78
......	Emmer	1.555	66.17	33.83

TABLE III. A comparison of varieties of barley, emmer, speltz and rye tested at the State Experiment Station, Manhattan, Kan. Spring barley arr ged in order of average yield for five years.

Bulletin No.	VARIETY.	Type of head.	Average 1907-'08-'09.			Yield, 1909.	Yield, 1908.	Yield, 1907.	Average yield, 1908-'09.	Average yield, 1907-'09.	Average yield, 1905-'09.	Average yield, 1903-'09.
			No. of days to mature.	Height in inches.	Weight per bushel.							
					lbs.	*bus*	*bus.*	*bus.*	*bus.*	*bus.*	*bus.*	*bus.*
20	Select Mansury	Six-row bearded	101	35.3	44.60	50.21	45.38	32.13	47.79	45.27	36.59	34.70
17	Stavropol	" "	100	30.6	46.60	39.79	46.89	31.87	43.34	39.52	34.95	....
21	Select Mandscheuri	" "	101	35.6	47.00	45.67	45.78	30.31	45.72	40.59	34.64	32.99
19	Selected Bonanza	" "	100	35.6	47.80	42.43	39.10	30.06	40.76	37.20	33.40	32.49
5	Common	" "	101	33.6	45.60	37.50	42.90	14.83	40.20	31.74	31.75	31.37
13	Six-row Ellis		100	30.3	41.10	32.46	44.50	9.27	38.48	28.74	28.58	....
8	Success Beardless	Six-row beardless	99	36.6	42.25	35.44	36.23	20.57	35.83	30.75	28.32	28.69
7	Bearded Hulless	Six-row bearded	100	29.3	59.10	32.43	37.04	21.08	34.37	30.18	27.54	25.65
15	U. S. 195		98	23.0	43.75	32.28	20.48	11.51	29.38	23.42	25.03	....
18	Select two-row Mandscheuri	Two-row bearded	103	36.6	46.41	17.03	12.54	19.09	14.78	16.22	*17.86	18.88
3	Tennessee winter barley	Six-row bearded	250	25.5	49.00	65.64	32.69	14.20	49.16	37.51	52.12	....
	Spring emmer		109	35.0	28.00	23.23	34.60	21.45	28.45	26.42	26.53	30.49
	Black winter emmer		271	41.0	29.00	....	57.00	25.00	....	....	....	....
	Winter speltz		262	38.0	28.00	....	53.23	64.27	....	....	....	....
11	Spring wheat	Durum	108	40.0	....	13.16	11.74	4.10	12.45	9.67	12.07	11.74
	Spring wheat	Fife or beardless	106	35.0	....	6.68	3.05	3.17	4.87	4.30	7.56	7.52
19	Winter wheat	Turkey	....	....	....	52.81	39.73	49.63	46.27	47.39	44.11	....
	Winter rye	Ivanhoff	254	49.6	....	41.91	38.74	....	40.32	....	†41.01	....

*Used yields of original seed for the years 1905-'06 to get average yields in this column.

†41.01, 1907 yield, not included.

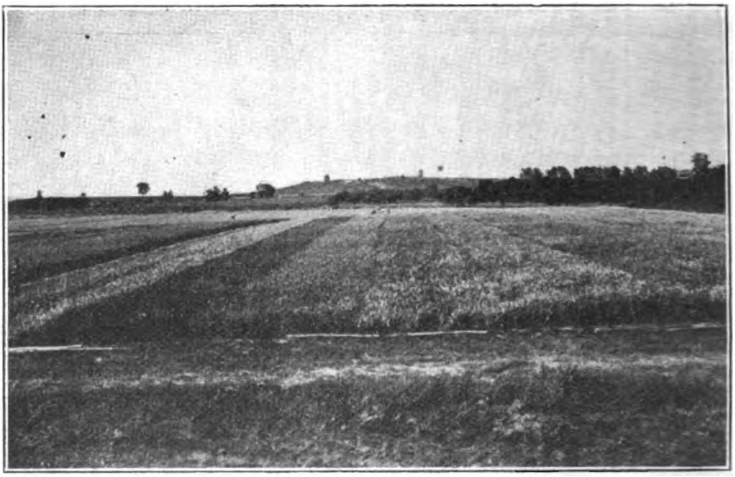

PLATE III. Testing varieties of barley in one-tenth-acre plots.

The Tennessee winter barley has yielded 15½ bushels more grain per acre for five years than the best producing variety of spring barley, while the spring emmer has yielded an average of ten bushels per acre less than the Mansury barley. Spring wheat has been an inferior producer compared with barley, oats and emmer. The Durum has yielded fifty per cent better than the ordinary spring wheat.

Winter wheat and winter rye have produced more bushels and more pounds of grain per acre than any of the other grains. The average yields for five years of the highest producing varieties in each class compare as follows: Winter wheat, 2647 pounds; winter rye, 2460 pounds; winter barley, 2461 pounds; spring barley, 1756 pounds; oats, 1632 pounds; emmer, 1189 pounds; Durum spring wheat, 724.2 pounds, per acre, respectively.

The winter varieties of emmer and speltz have outyielded the spring varieties during the years in which comparative trials have been made, as shown in table III.

Description and Adaptation of Varieties.

IMPROVED MANSURY. Six-rowed bearded type, medium early; best producing variety in seven years' trial; average yield, 34.7 bushels per acre. Best adapted for eastern and central Kansas.

IMPROVED BONANZA. Similar to Mansury in type and yielding qualities and adaptation for growing; average yield for seven years, 32.49 bushels per acre.

SIX-ROWED ELLIS. Bearded type, good yielder; average for five years, 28.58 bushels. Seed from Fort Hays Branch Station, Hays, Kan. Adapted for growing in western Kansas.

STAVROPOL. Six-rowed bearded type; one of the earliest maturing varieties and a good producer. Recommended for western and south-central Kansas. Average yield for five years, 34.95 bushels per acre.

SUCCESS BEARDLESS. Six-rowed barley, without beards. Adapted to all parts of the state; not so hardy and a little less productive than the best bearded varieties. Average yield for seven years, 28.69 bushels per acre.

EMMER. Spring emmer may take the place of barley or oats as stock feed, and may be somewhat more hardy and more drouth resistant in central and western Kansas. Emmer matures later than barley or oats, hence it is more likely to be injured by hot weather. Sow about three bushels of emmer per acre.

SPRING WHEAT. The tests of spring wheat indicate that it is not a profitable crop to grow at this Station. It is better adapted to the northern and northwestern portions of the state. The Durum should be preferred above other varieties of spring wheat for western Kansas, while for the northeastern part of the state the hard red spring wheat of the Fife or beardless type may succeed about as well as the Durum, and is preferred as a milling wheat.

II.—Improvement of Small Grains by Selection and Breeding.

The testing of varieties is necessarily an important factor in crop improvement, in order to learn which are best for planting under certain climate and soil conditions. The Agronomy Department is breeding by the "head-row" method eight varieties of winter wheat, five varieties of oats, four of barley, and one or more varieties each of spring wheat, emmer and winter rye. Thirteen hundred and forty separate head rows were planted in 1909. The work with most of these varieties has not progressed far enough to produce pedigreed seed in quantity for distribution.

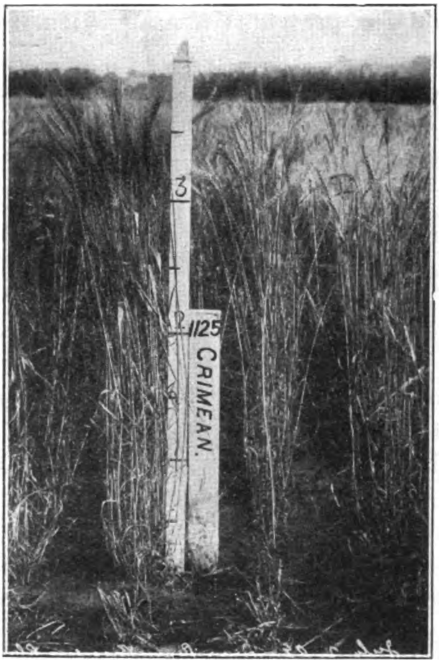

PLATE IV. Breeding head rows of Crimean wheat.

The yield secured from "head rows" indicates that certain individuals have much greater productive capacity than others of the same variety. For example, in a head-row test of Kharkof wheat in 1907-'08 the highest producing "head row" out of fifty yielded 349 per cent more grain than the lowest producing "head row," and 46 per cent more than the average yield from the fifty "head rows" in the test.

The head-row breeding work with oats and barley has given similar results. In a test of fifty heads of Red Texas oats, in 1909, the highest yielding row, No. 3, yielded 298.25 grams of grain, while the lowest yielding row, No. 44, produced 80.5 grams. The average yield of the fifty rows was 210.6 grams. The highest yielding row produced 270 per cent more grain than the lowest yielding row, and 42 per cent more grain than the average yield of all the head-test rows.

The 1909 head-row test of Mansury barley gave a variation in yields ranging from 62 grams per row to 299 grams per row. The average yield for the thirty rows in the test was 208.2 grams, or the highest yielding row produced 382 per cent more grain than the lowest producing row, and 44 per cent more grain than the average of the head test. The range in yield, height at maturity and the number of plants harvested for each of these rows is shown in table IV. It should be observed also that there was a marked variation in the quality of the grain produced by different "head rows." The quality and hardiness of the plants are considered as well as the yield in making breeding selections for further propagation.

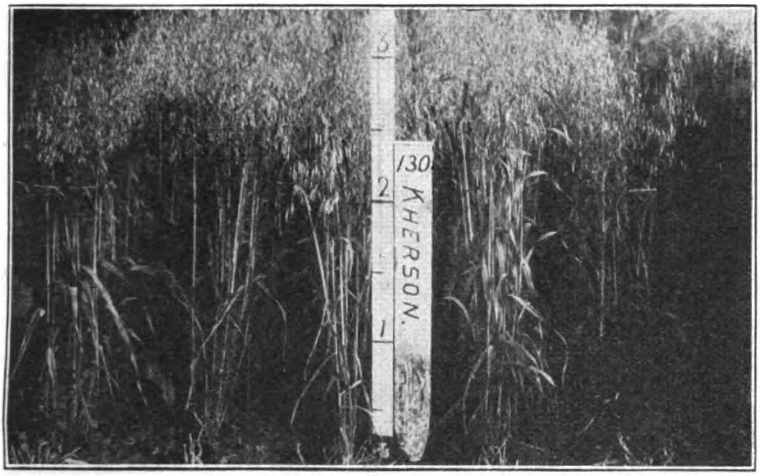

Plate V. Breeding head rows of Kherson oats.

Some forty of the best head-row selections of winter wheat were planted last fall (1909), in one-tenth-acre plots, for propagation and comparative testing, and a number of one-tenth-acre plots from the head-row selections of barley, oats

Table IV. Data from head test. No. 721 Mansury barley.

Row.	No. plants harvested...	Height at maturity....	Stooling, or number of heads......	Actual yield, grams.	Row.	No. plants harvested...	Height at maturity....	Stooling, or number of heads......	Actual yield, grams.
		ins.					*ins.*		
1...............	18	38	157	184.50	16...............	23	39	169	233.52
2...............	17	39	224	298.02	17...............	22	38	182	229.85
3...............	11	38	101	62.00	18...............	20	39	154	205.35
4...............	20	38	177	224.52	19	20	38	200	196.85
5...............	18	39	128	183.88	20...............	18	37	160	149.85
6...............	21	39	188	299.00	21...............	20	37	137	251.85
7...............	15	37	108	100.50	22...............	26	39	262	256.35
8...............	18	38	176	243.02	23...............	20	38	202	180.85
9...............	19	38	172	162.35	24...............	24	36	268	290.85
10...............	23	37	192	150.85	25...............	20	40	187	159.85
11...............	22	39	196	230.85	26...............	17	40	204	238.02
12...............	21	38	183	186.35	27...............	21	38	207	250.02
13...............	17	38	169	142.50	28...............	20	38	187	288.52
14...............	25	39	278	310.52	29...............	24	38	250	299.02
15...............	26	39	210	192.02	30.........	16	38	186	101.00

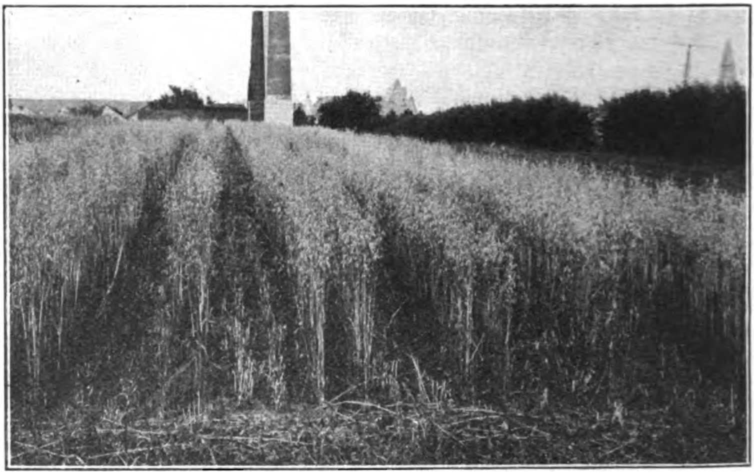

PLATE VI. Propagation rows of pedigreed oats. First year after head test.

and other grains will be planted this spring (1910). In two or three years sufficient seed of these improved strains should be produced to supply a limited demand throughout the state.

The seed grain distributed by the Agronomy Department up to the present time has been largely purified samples of the better producing varieties. The seed of Improved Red Texas oats, Selected Mansury and Selected Bonanza barley was secured by selecting a large number of good heads from the field, threshing the grain of these selected heads separately and planting in separate plots, from which seed was secured for further propagation. This general selection has produced some improvement over the original seed, as shown by the experiments with barley.

These selected strains of barley have been planted in test plots for three successive seasons in comparison with the original variety from which the selection was made. The yields and other data for the three selected strains of barley, compared with the original and average samples, are given in table V.

In each case the selected or improved strain has given a larger yield than the original seed, the Selected Mansury having produced a total of fourteen bushels more barley per acre in the three years than the original Mansury. Similar figures may be given for oats and for corn. No similar comparative tests with winter wheat have yet been made, but selections are now planted as stated above.

TABLE V. Selected and improved strains of barley compared with original variety.

Bulletin No.	VARIETY.	Type of head.	Average 1907-'08-'09.			Yield, 1909.	Yield, 1908.	Yield, 1907.	Average three years, 1907-'08-'09.	Average increased yield per acre, three years.	Total increased yield per acre, three years.
			No. of days to mature.	Height at maturity.	Weight per bushel.						
				ins.	*lbs.*	*bu.*	*bu.*	*bu.*	*bu.*	*bu.*	*bu.*
1	Mansury	Six-row bearded	100.6	34.0	37.75	36.46	44.06	32.94	37.82	....	....
20	Selected Mansury	" "	100.6	35.3	44.60	50.21	45.38	32.13	42.57	4.75	14.25
6	Bonanza	Six-row bearded	100.0	35.9	44.25	36.42	44.10	29.23	36.58	....	....
19	Selected Bonanza	" "	100.0	35.6	47.80	42.43	39.10	30.06	37.20	0.62	1.86
4	Two-row Mandscheuri	Two-row bearded	104.5	32.5	48.00	....	8.83	17.99	*13.41	....	....
18	Selected two-row Mandscheuri	" "	103.0	36.6	46.40	17.03	12.54	19.09	*15.82	*2.41	*7.23

* Average for two years, 1907-'08.

III.—Distribution of Improved Seed Grain.

The seed of the better producing varieties which the Agronomy Department has distributed is superior to the average seed which the farmers are growing, and the selected or improved strains are superior even to the original seed of the best producing varieties, as indicated by the comparative tests which have already been made. The seed which the Experiment Station will distribute in the future will be largely from the selected and pedigreed strains.

The seed distribution work was begun in 1904, but only a small quantity of seed was distributed in 1904 and 1905. The following is a brief summary of the number of bushels of seed distributed of each of the standard crops:

KIND OF CROP.	Bushels of seed distributed yearly.						
	1904.	1905.	1906.	1907.	1908.	1909.	Total.
Winter wheat	82.0	174.9	1,238.2	1,726.6	768.5	1,258.1	5,224,0
Winter barley		5.0	253.4	162.0	183.4	70.8	674.0
Winter rye					5.0	28.2	33.2
Oats	22.0	0.8	276.7	389.5	75.8	266.5	1,031.2
Spring barley	5.5	24.0	46.0	49.3	6.0	12.0	142.8
Emmer	2.0	12.0			13.0	15.8	42.8
Cane				69.0	78.0	110.0	257.6
Corn	40.2	294.5	422.7	561.7	344.8	714.7	2,378.0
Kafir			29.0	217.0	168.0	262.0	676.0
Milo maize					15.3	36.5	51.8
Broom corn			0.5		24.8	28.3	53.6
Soy beans	28.0		58.6	23.5	12.0	9.7	131.2
Cowpeas			8.9	12.7		14.5	36.1
Flax			15.0	28.6	10.5	1.5	55.6
Millet				1.0	5.8	0.5	7.3
Bromus inermis			0.5		4.2		4.7
Totals	125.5	511.0	2,350.0	3,241.0	1,715.0	2,845.7	10,796.0

These seeds were sold at a good price, and have been in great demand. The work has been well appreciated by the farmers, very few unfavorable reports having been received from the growers of the "College-bred" seed. Often farmers report yields of 25 to 30 per cent above that secured from unimproved home-grown seed planted in the same field or in adjacent fields. There is little question but that the sale and distribution of well-bred seed of these better producing varieties will have a marked influence in increasing the yield and improving the quality of our several standard grain crops, especially wheat and corn.

In the judgment of the writer this work is of vast impor-

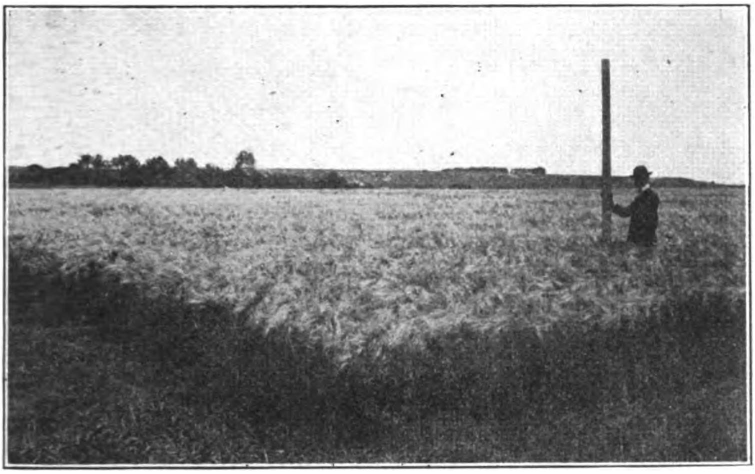

PLATE VII. A field of Tennessee winter barley on Experiment Station farm in 1906. Yield, 65 bushels per acre.

tance to the state. The improvement of crops by breeding and selection is primarily the work of the Experiment Station, and the Experiment Station should be the source or first distributer of well-bred seed. The general farmer cannot well undertake the improvement of crops by these expensive breeding methods, although he may grow the high-bred seed, and thus become a further distributer of improved seed grain.

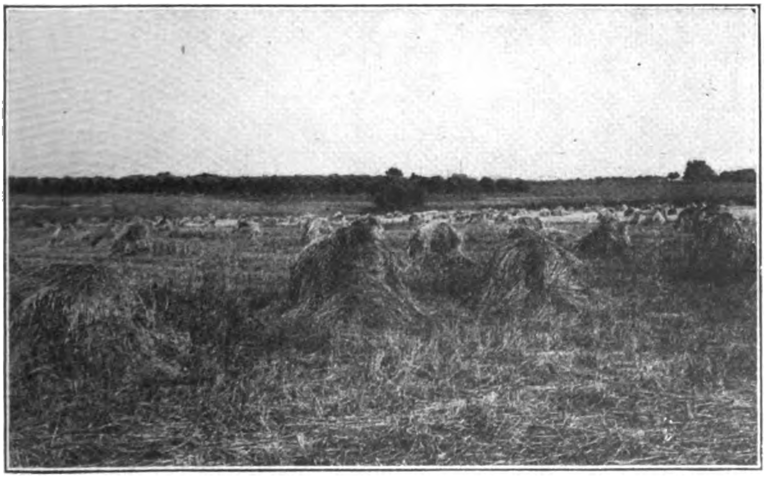

PLATE VIII. A field of pure-bred Ghirk wheat on Agricultural College farm. Crop of 1909. Yield, 52 bushels per acre.

THE FOLLOWING BULLETINS

ARE AVAILABLE FOR DISTRIBUTION.

No. 12....Preliminary Experiments with Fungicides for Stinking Smut of Wheat.
No. 15....Additional Experiments and Observations on Oat Smut.
No. 16....Experiments with Sorghum and with Sugar Beets.
No. 52....Kansas Weeds—Preliminary Circular on Distribution.
No. 120....Tests of Forest Trees.
No. 121....Treatment and Utilization of Flood-damaged Lands.
No. 129....Kansas Mammals in their Relation to Agriculture.
No. 136....Press Bulletins Nos. 125-151.
No. 137....Variations in the Test of Separator Cream.
No. 138....Effect of Bacteria in Wash-water of Butter.
No. 139....The Study of Corn.
No. 140....Milking Machines.
No. 141....Commercial Seeds of Brome-grass and of English and Kentucky Blue-grasses: Adulterants and Substitutes and their Detection.
No. 143....Disposal of Dairy and Farm Sewage, and Water Supply.
No. 144....Small-grain Crops.
No. 148....Law Regulating the Sale of Commercial Fertilizers.
No. 149....Prevention of Sorghum and Kafir-corn Smut.
No. 150....The Hen's Place on the Farm.
No. 154....The Mound-building Prairie Ant.
No. 155....Alfalfa.
No. 158....Analyses of Registered Feeding-stuffs.
No. 160....Cow-peas.
No. 162....The Marketing of Eggs.
No. 163....Hog Cholera and Vaccination.
No. 164....The Selection and Feeding of Laying Hens.
No. 165....Report of State Forester.

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Kansas State Agricultural College.

EXPERIMENT STATION.—Bulletin 167.

ED. H. WEBSTER, *Director*.

TECHNICAL BULLETIN.

Botanical Department.

H. F. ROBERTS, *Botanist in Charge*.

A Quantitative Method for the Determination of Hardness in Wheat.

BY

H. F. ROBERTS, *Botanist*.

MANHATTAN, KAN.
MARCH 15, 1910.
1902

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(Continued on third page of cover.)

(*a*) After May 31, 1910, A. M. TenEyck becomes superintendent of Fort Hays Branch Station.

(*b*) Begins work March 28, 1910.

A Quantitative Method for the Determination of Hardness in Wheat.

By H. F. ROBERTS.

SUMMARY.

1. The present bulletin gives an account of an apparatus designed to determine quantitatively, in terms of the mean crushing-point of the kernel, different degrees of hardness in wheat; this factor, or rather combination of factors, being considered indicative of superior milling quality in wheat of the *Triticum vulgare* types.

2. The ulterior purpose of this investigation is to establish a laboratory method for determining the relative hardness of pure strains of wheat; and finally to ascertain the degree of correlation existing between the hardness of the kernel and the chemical and physical characters of the gluten.

3. The present investigation involves the determination of the necessary number of kernels of wheat which must be used in order to arrive at a sufficiently correct average mean crushing-point for any given pure strain or variety.

4. It has been ascertained by a thorough investigation of two pure strains of wheat, the one hard, the other soft, that a correct average or mean crushing-point, accurately expressing in grams the degree of hardness of the particular races under investigation, was reached by taking the mean of the crushing-points of 350 kernels. Manifestly, quantitative estimates of hardness in any given pure strain of wheat will vary somewhat with the season and the locality.

5. The perfect concordance of the results of the experiments with the two strains of wheat chosen, Nos. 1115 and 1112, which have mean crushing-points of 6817 grams and 11,802 grams, respectively, for a total of 2700 kernels each, indicates that the facts disclosed by the investigations are probably general.

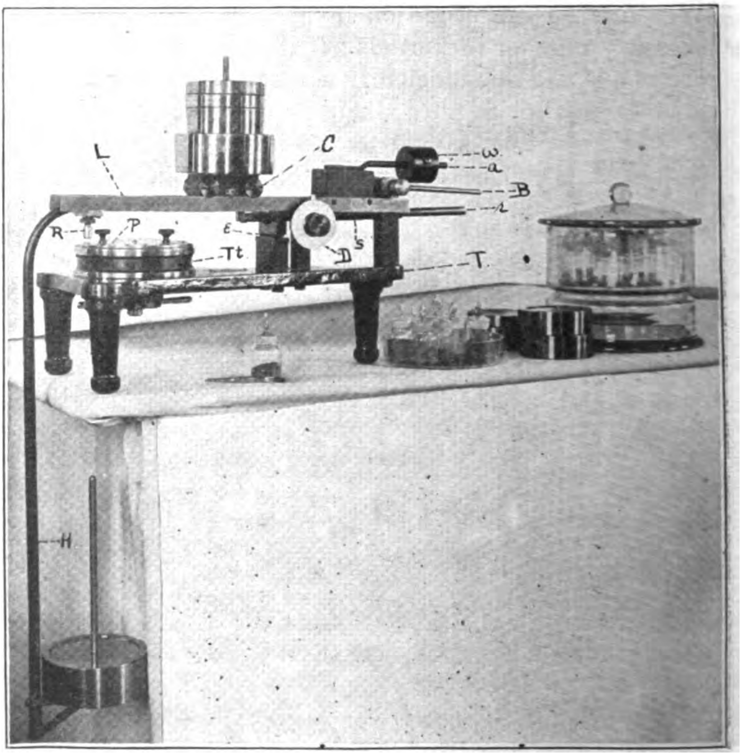
METHODS OF DETERMINATION.

To practical men of long experience in buying wheat of milling grades in the market, the present rough system of grading wheat is no doubt easy of exact application to particular cases.

In our work in wheat breeding, however, at the Kansas State Agricultural College and Experiment Station, it became necessary for scientific purposes to develop an exact and quantitative method for determining degrees of hardness in the wheat grain. It was found that no existing type of apparatus would in any way answer the purpose, and that it was therefore necessary to devise and construct one especially intended for this work. After some preliminary experiments, an instrument was designed with the aid of Mr. Wm. Gaertner, of Chicago, to whose ingenious and skillful assistance we are much indebted. This grain crusher, as illustrated in plate I, has been in constant use in our wheat investigations for the past two years, and has proved entirely successful and satisfactory in its operations. The new model of the machine, which embodies some needed improvements, is now to be had of Wm. Gaertner & Co.

The principle upon which the instrument depends for its

PLATE I.



construction is that of a lever in which the forces are located on the same side of the fulcrum. A table *T* supports a lever arm *L*, balanced on a knife-edge at *e* by a counter weight, *w*, which is adjustable along an arm, *a*. A carrier *C* which is removable runs on the top of the lever arm as a track upon four flanged wheels. A sliding rack arm *r*, running in a sleeve *s*, and actuated by a pinion set in motion by the revolution of the dial *D*, forms a connection beneath with the carrier *C*. The revolution of the dial *D* by the hand slides the carrier thus out along the track of the lever arm *L*, which bears a scale graduated to tenths and hundredths. At the end of the lever arm is a hanger *H*, which rests upon it with a knife-edge bearing surface. At the base of this hanger is a plate with an upright pin, on which perforated weights are strung. At *R*, fastened to the under side of the hanger end of the lever arm, is a ram or hammer which crushes the grains in succession, the latter lying in the pans *P* of the turntable or capstan *Tt*, which is revolved on a notched gear by means of spokes underneath the turntable (in the first model above it).

The weights are of brass, calibrated by the United States Bureau of Standards, and are in 1, 2 and 5 kilogram pieces.

The grains to be tested are first dried for seven days (in our our practice), at the boiling point of water, in the usual weighing bottles employed in analytical work, and which are then kept in a desiccator while the work is in progress. The grains are laid one at a time on the pans of the turntable, care being taken to place each grain in the same position (with the groove or crease down). Weights (preferably to nine kilograms for hard wheats) are mounted on the carrier *C*, which itself, detached, weighs a kilogram. The lever arm *L*, which is balanced before being weighted, is prevented from descending with the pull of the weighted hanger by means of a short lever at *B*, which operates on an eccentric brake. In operation the brake is slowly released after the machine has been weighted and the grain to be crushed has been brought into position. The ram *R* is thus carefully and gently brought to rest upon the upper surface of the kernel. The weighted carrier, which is at *O* on the lever arm scale, is now slowly moved out along its track by means of the rack-and-pinion gear mentioned, set in motion by revolving the disc *D*. By this means a constantly augmenting increment of weight is brought to bear upon the kernel, which finally gives way suddenly when the strain becomes too great. The crushing-point thus ascertained is the sum of the weight on the hanger arm, which, as it is brought to bear immediately over the kernel, is read directly, plus the fraction in 10ths and 100ths of the carrier weight, as read off on the lever arm scale. Thus, if the carrier weight (as we use it) amounts, with the carrier itself included, to 10 kilograms, and the grain when crushed finds the carrier pointer *P* at 7.2 on the lever arm, the pressure or weight which the ram *R* exerts on the kernel due to the influence of the carrier weight is .072 of 10 kilograms at that point, or 7.12 kilograms. By loading to 10 kilograms therefore the carrier weight can be read directly on the lever scale. With an odd number, such as 5 or 7 kilograms weight, the process in the case given of determining $\frac{5}{.072}$ would be tedious and time consuming. We therefore in our work with wheat, for which a combined carrier and hanger load of 15 kilograms is usually sufficient, load the carrier constantly to 10 kilograms, and increase the weight further if necessary before moving the carrier out. The dial *D* is graduated also to 10ths and 100ths of its circumference, in such manner that 10 spaces on the dial in revolution move the carrier pointer over one space on the lever arm scale. The dial thus reads in its smallest subdivisions to grams, in terms of the increasing pressure of the carrier weight due to its revolution.

The machine above described and figured is now in its second model, and has been thoroughly tested in our work of grading pure-bred wheats on a scale of hardness. In general, we find that "soft" wheats crush under a pressure of 6000 grams or less (13 pounds), "semi-hard" wheats at about 9000 grams (20 pounds), and "hard" wheats at 12,000 grams and over (26 pounds and over).

It immediately became a question, after a series of preliminary tests, as to how many kernels it might be necessary to crush in order to arrive at an approximately correct average estimate of the hardness of the race of wheat under experiment. To this end two pure strains were selected—one, No. 1115, a soft wheat, and another, No. 1112, a hard strain.

From each of these races 2700 kernels were taken at random, and, after having been dried for seven days at the boiling point of water, were crushed in succession; the crushing-point in grams for each kernel being recorded separately. With the data thus obtained a series of groups was formed by taking *seriatim,* and consequently without selection, the data of the crushing-points as variates, thrown into nine successive groups, containing in each, respectively, 100, 150, 200, 250, and so on up to 500 variates. In this manner no single variate was used twice, and the means, standard deviations and errors of the means were calculated for each of the nine groups in the case of each of the two strains under experiment.

From the above data it was anticipated that a plotting of the errors of the mean crushing-points for successively increasing groups of variates might throw light on the minimum number of variates necessary to be crushed in order to arrive at a sufficiently correct mean crushing-point for any race of wheat.

In the case of No. 1115, for which the calculations were first made, the deviations from the mean were first taken as originally determined in grams. In the case of so many groups with such a large number of variates in most of them, and with all of the data expressed in thousands of grams, the reduction of the data became excessively tedious. However, the standard deviations and errors of the mean were calculated for the entire nine groups of No. 1115, using the data of the crushing-points exactly as found in grams. For comparison,

TABLE I.

Wheat No. 1115. Constants for 2700 kernels.

Groups of variates.	No. of variates in group........	A.—Crushing-points of variates in grams.				B.—Crushing-points of variates in kilos.			
		Mean crushing-point (gms.)	Error of mean crushing-point (gms.)	Standard deviation (grams).	Error of standard deviation (gms.)	Mean crushing-point (kilos).	Error of mean crushing-point (kilos).	Standard deviation (kilos).	Error of standard deviation (kilos).
Group I	100	7035	72.12	1069.32	51.00	7.00	0.0729	1.0802	0.0515
" II	150	7062	63.71	1156 85	45.05	7.10	0.0638	1.1587	0.0451
" III	200	6981	51.34	1076.55	36.31	7.00	0.0532	1.1155	0.0376
" IV	250	6943	56.93	1334.55	40.56	6.90	0.0571	1.3378	0.0404
" V	300	6852	45.67	1172.91	32.30	6.80	0.0462	1.1873	0 0327
" VI	350	6658	41.43	1149.15	29.30	6.60	0.0377	1.1558	0 0295
" VII	400	6560	42.90	1272.10	30.34	6.50	0.0434	1.2881	0.0307
" VIII	450	6499	35.35	1111.86	25.00	6.50	0.0351	1.1059	0.0282
" IX	500	6764	38.37	1271.89	27.13	6.71	0.0367	1.2159	0.0259

NOTE.—Multiplying the data under "B" by 1000, the close correspondence of the constants calculated from the crushing-points expressed in kilos and tenths of kilos, with those calculated from the data as originally determined in grams, will be readily seen.

TABLE II.

Wheat No. 1112. Constants for 2700 kernels.

Groups of variates.	No. of variates in groups.....	Crushing-points of variates (reduced to kilos and tenths of kilos).			
		Mean crushing-point (kilos).	Error of mean crushing-point (kilos).	Standard deviation (kilos).	Error of standard deviation (kilos).
Group I...	100	12.3	0.1398	2.0729	0.0989
" II...	150	11.7	0.1234	2.2403	0.0872
" III...	200	11.7	0.1107	2.3215	0.0774
" IV...	250	11.5	0.1078	2.5259	0.0762
" V...	300	11.9	0.0880	2.2596	0.0622
" VI...	350	11.8	0.0846	2.3481	0.0598
" VII...	400	11.8	0.0856	2.5380	0.0605
" VIII...	450	10.5	0.0854	2.6860	0.0604
" IX...	500	12.0	0.0716	2.3731	0.0506

however, a second calculation was made, reducing the crushing-points from grams to kilos and tenths of kilos, which was found to materially diminish the labor without impairing the value of the results. This method was therefore followed in the case of No. 1112, in which the data were reduced to kilos and tenths for purposes of computation.

It then became a question as to how many kernels it would be necessary to crush in order to arrive at the best expression of the mean crushing-point of a given pure strain, and thereby

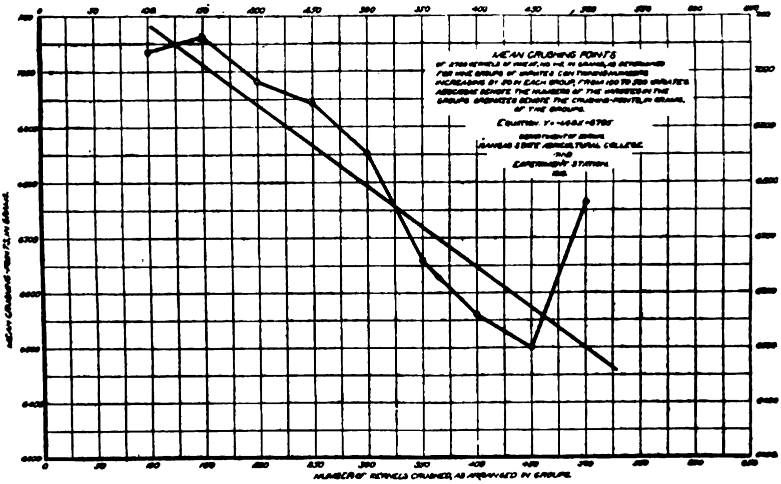


PLATE II. MEAN CRUSHING-POINTS

Of 2700 kernels of wheat No. 1115, in grams, as determined for nine groups of variates containing numbers increasing by 50 in each group, from 100 to 500 variates. Abscissæ denote the numbers of variates in the groups. Ordinates denote the crushing-points, in grams, of the groups. Equation: $y = -1.48x + 6795$.

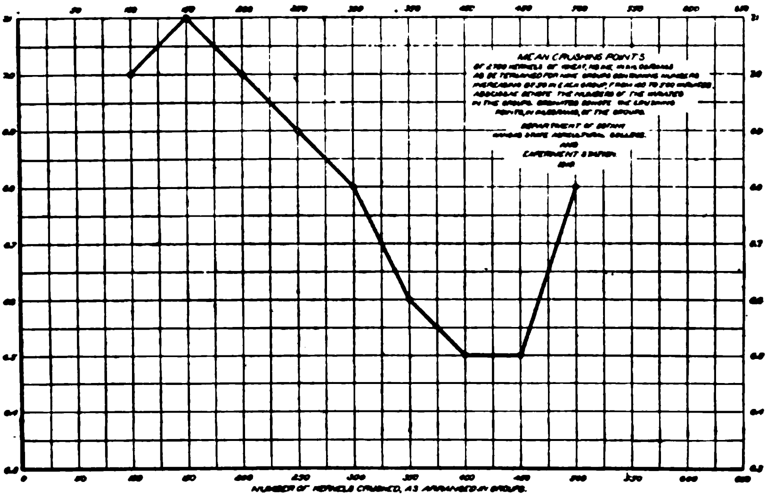


PLATE III. MEAN CRUSHING-POINTS

Of 2700 kernels of wheat No. 1115, in kilograms, as determined for nine groups containing numbers increasing by 50 in each group, from 100 to 500 variates. Abscissæ denote the numbers of the variates in the groups. Ordinates denote the crushing-points, in kilograms, of the groups.

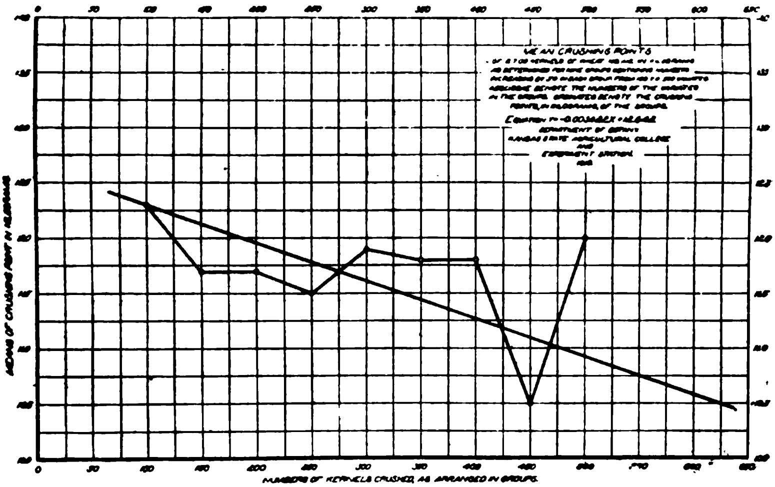


PLATE IV. MEAN CRUSHING-POINTS

Of 2700 kernels of wheat No. 1112, in kilograms, as determined for nine **groups** containing numbers increasing by 50 in each group, from 101 to 500 variates. Abscissæ denote the numbers of the **variates** in the groups. Ordinates denote the crushing-points, in kilograms, of the **groups. Equation**: y = −0.003422 × +12.642.

of its hardness for grading purposes. By taking the means of increasingly large groups of variates as described above, and by calculating the error of the mean for each group, it was anticipated that the decrease in the error of the mean, with the increasing numbers of the variates used, would be the best possible criterion for the least number of variates necessary to be used in determining the mean crushing-point of the race.

Taking the two pure strains—No. 1115, a soft wheat, and No. 1112, a hard or semi-hard wheat—2700 kernels were crushed in the manner previously described. Plotting the mean crushing-points, we have the following curves. Plate II shows the mean crushing-points of No. 1115 plotted in grams, as the data were originally obtained. Plate III shows the same data arranged and plotted in kilos. Plate IV shows the mean crushing-points for No. 1112, which, although originally determined in grams, were plotted in kilos.

The following table gives the means of the nine groups of both 1115 and 1112, as actually determined in grams, and also as reduced to kilos, for purposes of comparison.

TABLE III.

Groups of variates.	No. of variates in groups....	No. 1115. Mean crushing-points in grams.	No. 1115. Mean crushing-points reduced to kilos and tenths of kilos.	No. 1112. Mean crushing-points in grams.	No. 1112. Mean crushing-points reduced to kilos and tenths of kilos.
Group I	100	7,035	7.00	12,277	12.3
" II	150	7,062	7.10	11,706	11.7
" III	200	6,981	7 00	11,738	11.7
" IV	250	6,943	6.90	11,496	11.5
" V	300	6,852	6.80	11,925	11 9
" VI	350	6,658	6 60	11,772	11 8
" VII	400	6,560	6.50	11,808	11.8
" VIII	450	6,499	6.50	10,496	10 5
" IX	500	6,764	6.70	12,000	12 0

No. 1115 is a derivative of a selection made in 1906 of a single head from a plot of our No. 611, called "Turkey," and received originally from the United States Department of Agriculture (U. S. Dept. No. 1676). It is a bearded wheat with white glumes, of the general "Turkey" type. No. 1112 is a derivative of a selection also made in 1906 of a single head from a plot of our No. 609, also called "Turkey," and also received originally from the United States Department of Agriculture (U. S. Dept. No. 1658). It is a wheat of the bearded type, with red glumes.

It will be noted from plate II that the mean crushing-point regularly falls from 7000 to 6500 grams in the progression from the group containing 100 to that containing 450 variates. However, the group 500 shows an astonishing rise to a mean of 6764 grams. This deflection from the straight line curve to which the remaining moments readily plot will be discussed later.

Plate III, in which the same data exhibited in plate II are plotted in kilos and round tenths, instead of in grams, reduces the irregularities in the central portion of the curve.

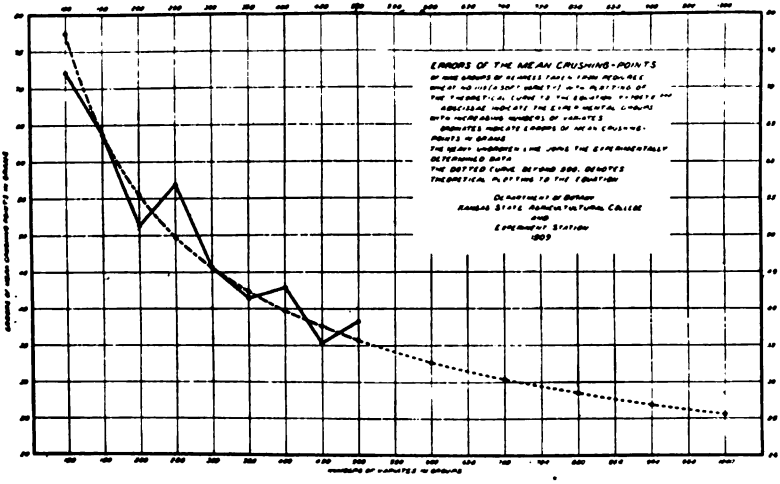


PLATE V. ERRORS OF THE MEAN CRUSHING-POINTS

Of nine groups of kernels taken from pedigree wheat No. 1115 (a soft variety), with plotting of the theoretical curve to the equation $y = 705.7x^{-0.48}$.
Abscissæ indicate the experimental groups with increasing numbers of variates.
Ordinates indicate the errors of mean crushing-points, in grams.
The heavy unbroken line joins the experimentally determined data.
The dotted curve beyond 500 denotes the theoretical plotting to the equation.

In plate IV the ordinates, for convenience in plotting, are on a scale of 1:0.5 kilos, while in plates II and III the ordinates are plotted to a scale of 1:0.1 kilos. Plotted to the same scale as plates II and II, the irregularities in the curve of No. 1112 as compared with No. 1115 would have been very much more pronounced. It will suffice here to call attention to the same marked rise in the mean crushing-point of the 500 group of No. 1112 (in comparison with the 450 group) as was seen in No. 1115. Plotting the errors of the mean crushing-points exhibited in table II, we have for No. 1115 the curve as plotted in plate V, in which the abscissæ denote the groups, with the numbers of the variates in each, and the ordinates denote the errors of the mean crushing-point in grams. In this curve the heavy unbroken line joins the moments of the curve as determined from the experimental data, and as shown in table I under No. 1115, in the column entitled "Errors of the mean crushing-point (grams)." The broken line approximating a hyperbolic curve forms the probable best expression of the relation of the data in question, and plotted to the equation $y = 705.7x^{-0.48}$. The dotted line continues the theoretical curve beyond the last experimental datum to a datum with 1000 variates.

Likewise in plate VI is shown a plotting of the errors of the mean of wheat No. 1112, for a similar series of nine groups, having the same numbers of variates in each, as in the case of No. 1115. Here the approximate hyperbolic curve plots to the equation $122.5x^{-0.45}$.

(Note here the similarity in the exponents of the two curves, differing by only .03, which would suggest that, allowing for experimental error, the probable exponent for both would be 0.50.)

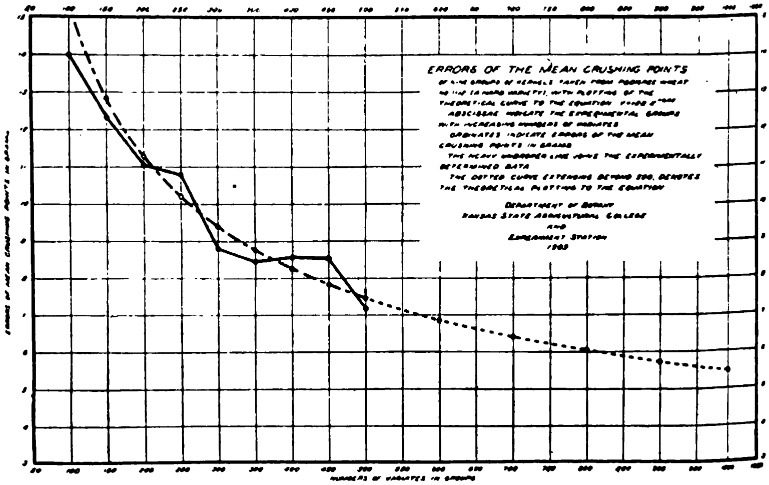


PLATE VI. ERRORS OF THE MEAN CRUSHING-POINTS

Of nine groups of kernels taken from pedigree wheat No. 1112 (a hard variety), with plotting of the theoretical curve to the equation, $y = 122x^{-0.45}$.

Abscissæ indicate the experimental groups with increasing numbers of variates.

Ordinates indicate errors of the mean crushing-points, in grams.

The heavy unbroken line joins the experimentally determined data.

The dotted curve extending beyond 500, denotes the theoretical plotting to the equation.

For those who may be interested in noting the derivation of the equation in the two cases, the mathematical data are given, as follows:

No. 1115.

Let equation be $y = bx^n$

Then, –

(1) $\log.\ y = \log.\ b + n \log.\ x.$

Taking two points on the experimental curve, $x = 150$ and $x = 300$—

When $x = 150$

$y = 63.71$ (See table I. A.)

$\log.\ x = 2.1761$

$\log.\ y = 1.8042$

When $x = 300$

$y = 45.67$

$\log.\ x = 2.4771$

$\log.\ y = 1.6597$

Substituting in (1) and combining:

(2) $1.8042 = \log.\ b + n\ (\ 2.1761)$

$$(3)\ \begin{array}{l}\underline{1.6597 = \log.\ b + n\ (\ 2.4771)}\\ .1445 = \qquad\qquad n\ (-.3010)\end{array}$$

$$n = \frac{.1445}{-.3010} = -0.48$$

Substituting in (1) and solving for b:

(5) $\log.\ b = 2.8487$

(6) $b = 705.7$

Then, when $y = bx^n$

(7) $y = 705.7x^{-0.48}.$

Taking a point on the experimental curve, $x = 100$—

Substituting in (1)

(1) $\log.\ y = \log.\ b + n \log.\ x.$

From (7), $\log.\ y = 2.8487 + (-0.48 \times 2.0000)$

(8) $\log.\ y = 1.8887$

(9) $y = 77.39$, where experimental $y = 72.12.$

Calculating similarly for all remaining points on the experimental curve, under the assumed equation,

$y = bx^n$, or,

$y = 705.7x^{-0.48}$, we have,

TABLE IV.

	Theoretical.	Experimental.	Corrections for experimental curve + or − are additive.
Where x = 100	y = 77.39 g.	y = 72.12 g.	+ 5.27 g.
200	55.49	51.34	+ 4.15
250	49.85	56.93	− 7.08
350	42.41	41.43	+ 0.98
400	39.78	42.90	− 3.12
450	37.60	35.35	+ 2.25
500	35.74	38.37	− 2.63

Considering the close approximation of the experimental curve to the equation $y = bx^n$, when $b = 705.7$ and $n = -0.48$, and the close balancing of errors, it is concluded that this equation expresses the condition with respect to the errors of the mean crushing-points of a pure-bred wheat (No. 1115), under the conditions of the experiment.

Now, plotting the curve beyond the experimental data, we therefore have—

TABLE V.

Where x = 600	y = 32.75 g.
700	30.42
800	28.52
900	26.96
1000	25.63

Similarly in the determination of the equation for the curve of errors of mean crushing-points in wheat No. 1112:

Let equation be $y = bx^n$.
Then,
(1) $\log. y = \log. b + n \log. x$.

Taking two points on a hypothetical curve, $x = 275$ and $x = 375$.

When $x = 275$
$y = 9.78$
$\log. x = 2.4393$
$\log. y = 0.9903$

When $x = 375$
$y = 8.50$
$\log. x = 2.5740$
$\log. y = 0.9294$

Substituting in (1) and combining:

$$\begin{array}{ll} (2) & .9903 = \log. b + n\ (2.4393) \\ (3) & \underline{.9294 = \log. b + n\ (\ \ 2.5740)} \\ & .06909 = \qquad n\ (-0.1347) \end{array}$$

$$(4)\ n = \frac{.0609}{-.1347} = -0.45$$

(5) $\log. b = 2.088$
(6) $b = 122.5$

Then, when $y = bx^n$.
(7) $y = 122.5x^{-0.45}$.

Calculating all the points on the experimental curve, we have—

TABLE VI.

	Theoretical.	Experimental.	Corrections for experimental curve + or —, are additive.
Where x = 100	y = 13.98	y = 15.45	— 1 47
150	12.34	12.84	— 0.50
200	11.07	11.30	— 0.23
250	10.78	10.21	+ 0.49
300	8.80	9.40	— 0.60
350	8.46	8.77	— 0.31
400	8.56	8.26	— 0.30
450	8.54	7.83	— 0.71
500	7.16	7.48	— 0.32

Again a close fitting of the curve to the experimental data.

Plotting the theoretical curve beyond the determined data, we have—

TABLE VII.

Where x = 600	y = 17.85 g.
700	19.00
800	20.25
900	21.40
1000	22.40

It was thought desirable to determine the rate of decrease of the error of the mean crushing-point (y), for successively increasingly large numbers of kernels crushed (x); in other words, the differential of y with respect to x, or $\frac{dy}{dx}$, in the two cases under experiment, where (No. 1115) $y = 705.7x^{-0.48}$, and (No. 1112) where $y = 122.5x^{-0.48}$.

Where, $y = 705.7x^{-0.48}$, differentiating, we have

$$\frac{dy}{dx} = d\,\frac{(705x^{-0.48})}{dx} = -0.48\,(705.7x^{-1.48}) = \frac{-0.48 \times 705.7.}{x\,1.45} \text{ and,}$$

$$\log. \frac{dy}{dx} = \log.\ 0.48 + \log.\ 705.7 + 1.48 \text{ colog. } x\text{; and similarly,}$$

$$\text{where } y = 122.5x^{-0.45} \text{ we have } \log. \frac{dy}{dx}, = \log.\ 0.45 + 1.45 \text{ colog. } x.$$

From the last two equations, determining $\frac{dy}{dx}$ for each of the groups in the two cases, Nos. 1115 and 1112, we have—

TABLE VIII. (No. 1115.)

When x = 100	$\frac{dy}{dx}$ = —.371616
150	—.203819
200	—.133048
250	—.095699
300	—.073067
350	—.058162
400	—.047732
450	—.040096
500	—.034307

TABLE IX. (No. 1112.)

When x =	$\frac{dy}{dx}$ =
100	−.0691434
150	−.0384077
200	−.0253079
250	−.0183121
300	−.0140580
350	−.0112422
400	−.0092632
450	−.0078089
500	−.0067026

Having determined in terms of the differential $\frac{dy}{dx}$, in the case of No. 1115 and No. 1112, the *rate* of *change* in respect to the diminution of the error of the mean crushing-point with successively increasing numbers of grains selected for crushing, it becomes now a question as to the *relative differences* in this rate of change as the groups chosen for crushing become larger and larger, or, to use more familiar terminology, what is the *rate* of *negative acceleration* of the errors of the mean crushing-point with successively increasing values of x. We have, for No. 1115,

(1) $\frac{dy}{dx} = -0.48 \times 705.7x^{-1.48}$

(2) hence, $\frac{d^2y}{dx^2} = -1.48 \times -0.48\ (705.7x^{-2.48});\ = 501.029x^{-2.48}$

(3) log. $\frac{d^2y}{dx^2}$ = log. 501.029 − 2.48 log. x.

From which we have, in the case of No. 1115,

TABLE X.

When x =	$\frac{dy}{dx}$ =	$\frac{d^2y}{dx^2}$ =	Differences.
100	−.371616	0.00549696	
150	−.203819	0.00201102	.00348594
200	−.133048	0.00098530	.00102572
250	−.095699	0.00056654	.00041876
300	−.073067	0.00036046	.00020608
350	−.058162	0.00024594	.00011452
400	−.047732	0.00017661	.00006933
450	−.040096	0.00013187	.00004474
500	−.034307	0.00010154	.00003033

From the second differential, $\frac{d^2y}{dx^2} = 501.029x^{-0.48}$, we derive the equation for the *negative acceleration in the rate* of decrease in the error of the mean crushing-point with increased values of x. In other words, we have the equation for the *retardation in the rate of decrease* of the error of the mean, for the increasing size of the groups of variates selected for crushing.

The equation in the case of No. 1115 would be $y = \frac{501.029}{x^{-2.48}}$ or, in other words, y = the series of the second differentials as determined for table X for successive values of x.

Determining likewise the second differential in the case of No. 1112—

$$(1)\ \frac{dy}{dx} = 0.45 \times 122.5x^{-1.45}$$

$$(2)\ \frac{d^2y}{dx^2} = -1.45 \times 0.45 \times 122.5^{-2.45};\ = 187.739x^{-2.45}$$

$$(3)\ \log.\ \frac{d^2y}{dx^2} = \log.\ 187.739 - 2.45 \log.\ x.$$

From which we have, in the case of No. 1112—

TABLE XI.

Where x =	$\frac{dy}{dx}$ =	$\frac{d^2y}{dx^2}$ =	Differences.
100	− .0691484	0.00236849	
150	− .0384077	0 00087525	.00148824
200	− .0253079	0.00043254	.00044271
250	− .0183121	0.00025038	.00018216
300	− .0140580	0.00016018	.00009020
350	− .0112422	0 00010979	.00005039
400	− .0092632	0.00007916	.00003063
450	− .0078089	0.00005931	.00001985
500	− .0067026	0 00004582	.00001349

The equation in the case of No. 1112 would be $y = \frac{187.739}{x^{-2.45}}$.

Plotting the two equations, with the numbers of variates in the groups as abscissæ, and the differentials as ordinates, we have in plates VII and VIII the graphs for the first and second differentials, respectively, for each of the strains, 1115 and 1112.

To make the matter entirely clear to those not interested in the mathematical expressions: the curve in plate VII represents the *rate* at which the *error of the mean crushing-point decreases* as we proceed to take groups of kernels for crushing which contain a larger and larger number of individuals, the number in such groups being indicated on the horizontal axis (the x-axis). This is what is known as the first differential. The rapid lessening of this differential in the first few groups is indicative of the immense gain, so far as the cutting down of the error of the mean is concerned, derived from taking say, 150 or 250 kernels, instead of 100. The rapid slowing down of this rate of decrease when we reach 350 kernels is sufficiently plain. It therefore appears evident that our empirical choice of 350 kernels as the optimum practical number for crushing, to determine the mean crushing-point of a given pure race of wheat, is perfectly justifiable.

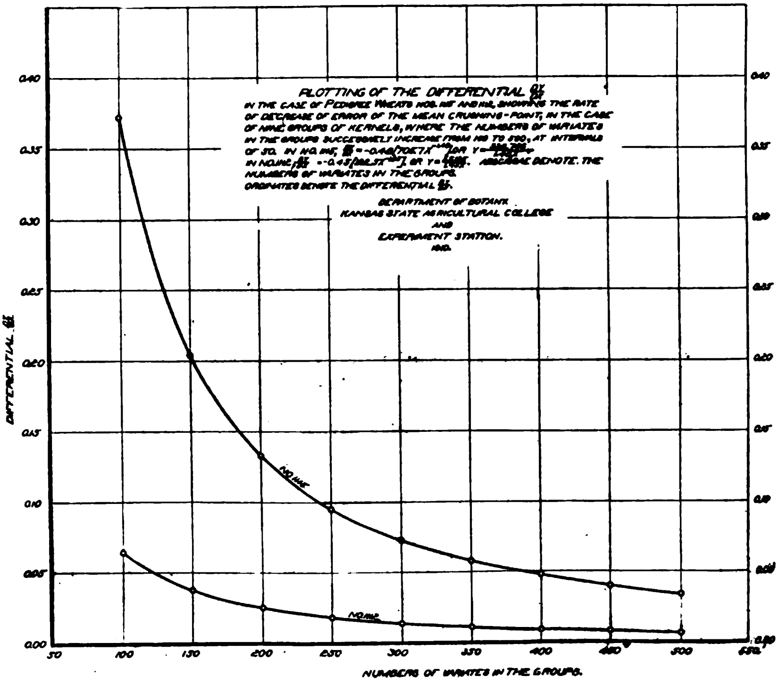


PLATE VII. PLOTTING OF THE DIFFERENTIAL $\frac{DY}{DX}$.

In the case of pedigree wheats Nos. 1115 and 1112, showing the rate of decrease of error of the mean crushing-point, in the case of nine groups of kernels, where the numbers of variates in the groups successively increase from 100 to 500, at intervals of 50.

In No. 1115. $\frac{dy}{dx} = -0.48\ (705.7x^{-1.48})$, **or** $y = \frac{338.736}{1.48x}$.

In No. 1112. $\frac{dy}{dx} = -0.45\ (122.5x^{-1.45})$, **or** $y = \frac{55.125}{1.45x}$.

Abscissæ denote the numbers of variates in the groups.

Ordinates denote the differential $\frac{dy}{dx}$.

In plate VIII we have likewise the graph or curve for the second differential, which expresses not the *rate of decrease* itself, but the *rate of speed* at which *that rate slows down.*

In more general terms, the first differential expresses *velocity,* while the second differential expresses *acceleration.*

The velocity may be an increasing or a decreasing one; and likewise, instead of *positive* acceleration, we may have *negative* acceleration or retardation.

In the present case we are dealing of course with a decreasing velocity and a negative acceleration.

The curve of the second differential shows finally the fundamental object of the investigation—to discover *at what point*

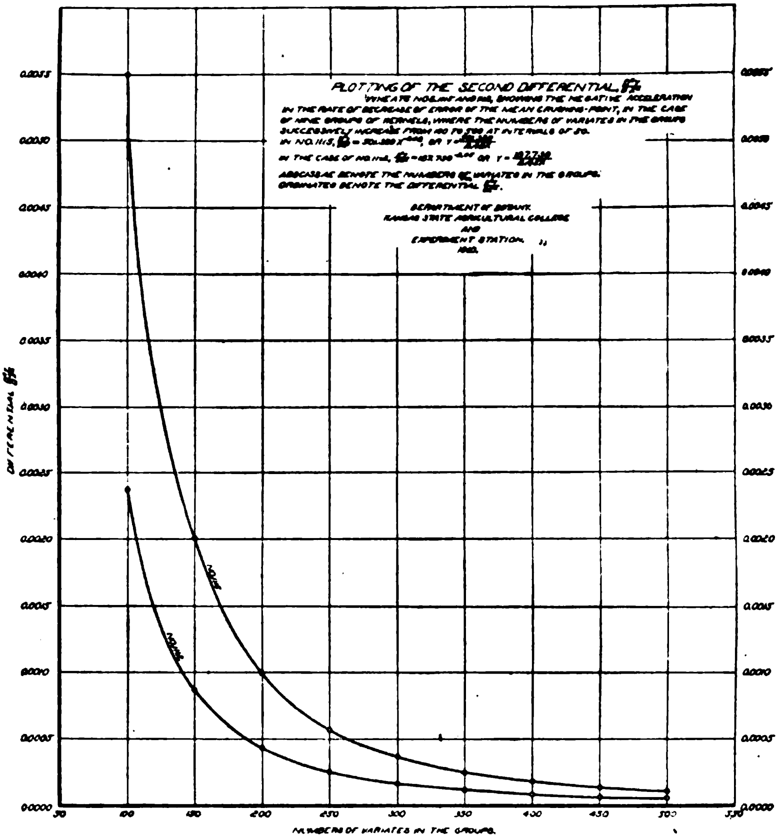


PLATE VIII. PLOTTING OF THE SECOND DIFFERENTIAL $\frac{D^2Y}{DX^2}$,

Wheats Nos. 1115 and 1112 showing the negative acceleration in the rate of decrease of error of the mean crushing-point, in the case of nine groups of kernels, where the numbers of variates in the groups successively increase from 100 to 500 at intervals of 50.

In No. 1115, $\frac{d^2y}{dx^2} = 501.829x^{-2.48}$, or $y = \frac{501.829}{2.48x}$.

In the case of No. 1112, $\frac{d^2y}{dx^2} = 187.789^{-2.45}$ or $y = \frac{187.789}{2.45x}$.

Abscissæ denote the number of variates in the groups.

Ordinates denote the differential $\frac{d^2y}{dx^2}$.

the rate at which the diminishing error falls off—becomes itself so slight as to be negligible.

The graph in plate VIII shows most convincingly that the critically important point in this respect is more than reached at the 350-variate group.

Referring back to plate II and table I, it will be noted that the mean crushing-point, which falls off steadily to 6499 grams at the 450-variate point, suddenly rises at the 500-variate point to 6764. This sudden deflection of the curve calls for investigation, as it clearly does not harmonize with the other points of the curve. In order to analyze the data more precisely, a mean was taken of each successive hundred variates in the original raw data of individual crushing-points. These means of twenty-seven successive hundreds are given as follows:

TABLE XII.

Group.		Mean crushing-point.	
First	100	7025	grams.
Second	100	7112	“
Third	100	7043	“
Fourth	100	6977	“
Fifth	100	6938	“
Sixth	100	7056	“
Seventh	100	6784	“
Eighth	100	6885	“
Ninth	100	6962	“
Tenth	100	6708	“
Eleventh	100	6726	“
Twelfth	100	6681	“
Thirteenth	100	6461	“
Fourteenth	100	6422	“
Fifteenth	100	6667	“
Sixteenth	100	6773	‘
Seventeenth	100	6451	“
Eighteenth	100	6605	“
Nineteenth	100	6447	“
Twentieth	100	6434	“
Twenty-first	100	6099	“
Twenty-second	100	6865	“
Twenty-third	100	6731	“
Twenty-fourth	100	6673	“
Twenty-fifth	100	6598	“
Twenty-sixth	100	6639	“
Twenty-seventh	100	6983	“

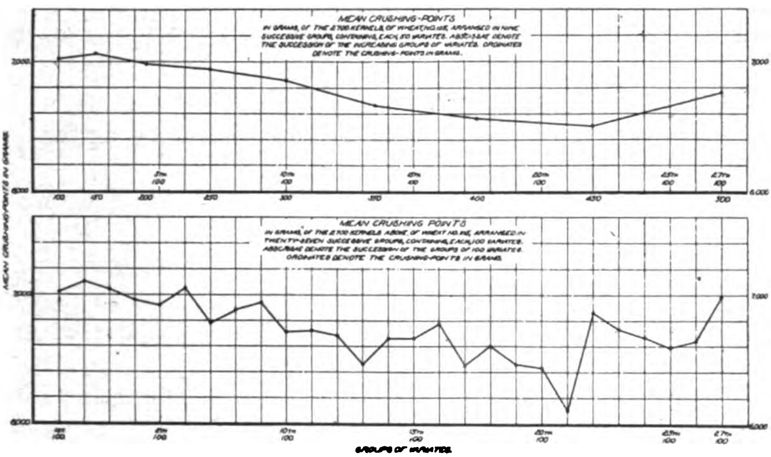


PLATE IX. (Upper graph.) MEAN CRUSHING-POINTS,

In grams, of the 2700 kernels of wheat No. 1115, arranged in nine successive groups, containing each 50 variates more than the next preceding group. Abscissæ denote the succession of the increasing groups of variates. Ordinates denote the crushing-points, in grams.

PLATE IX. (Lower graph.) MEAN CRUSHING-POINTS,

In grams, of the 2700 kernels above, of wheat No. 1115, arranged in twenty-seven successive groups, containing each 100 variates and showing the individual variation of the groups. Abscissæ denote the succession of the groups of 100 variates. Ordinates denote the crushing-points, in grams.

Plotting these, we have the lower graph shown on plate IX, with the graph for the mean crushing-points of the nine successively increasing groups plotted on the same scale above for comparison. The lower curve shows the individual variation in the groups of 100 each, and it is to be seen that whereas the eleven successive hundreds, from the tenth to the twentieth, inclusive, all had means beween 6400 and 6800 grams, the last five successive hundreds, from the twenty-second to the twenty-seventh, inclusive, had means lying between 6600 and 7000. The upper curve thus having its components analyzed in the lower one, renders it possible to see exhibited there the details of the sudden rise in the mean crushing-point of the last group previously referred to, in the upper curve of plate IX. The abrupt rise of this 500 group, as contrasted with its immediately preceding one containing 450 variates, is especially striking. No way has been found to account for this sudden upward displacement of the mean crushing-points in the last five groups of 100 variates each, unless on the theory that the prolonged delay of the kernels of the last series in the desiccator while awaiting crushing would tend to increase the relative hardness of this particular lot. However, the sudden increase in mean crushing-point in this series, as shown in the upper graph of plate IX, and more strikingly on the larger scale of plate II, does not affect the general condition of the curve, and it may therefore, as the one erratic moment, be neglected.

Finally, the investigation has in mind as its main ultimate objects:

First. The discovery of the correlation of hardness, as determined in terms of the mean crushing-point, with certain chemical factors of economic importance, to be discussed in a succeeding bulletin.

Second. It is desired to assist in laying the foundation for a standard system of grading wheat on the basis of economic values to be determined quantitatively. That there is a definite relation between hardness in wheat and these economic factors is generally admitted.

The present machine used in determining the crushing-point of wheat, while perfectly accurate, needs to be modified in such a way as to increase the speed of its operation, and a number of changes are being considered to this end. Any scientific method of wheat grading must admit of great rapidity of operation, in order to be of practical commercial value.

STATION STAFF.

Continued from second page of cover.

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- J. B. PARKER, Assistant in Staple Crop Insect Investigations.
- H. P. EVANS, Assistant in Fruit Insect Investigations.
- T. H. SCHEFFER, Assistant in Zoölogical Insect Investigations.

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(c) Begins June 1, 1910.

(d) Began March 1, 1910.

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No. 12....Preliminary Experiments with Fungicides for Stinking Smut of Wheat.
No. 15....Additional Experiments and Observations on Oat Smut.
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No. 43....Experiments with Sorghum and with Sugar Beets.
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AGRICULTURAL EXPERIMENT STATION,
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Kansas State Agricultural College.

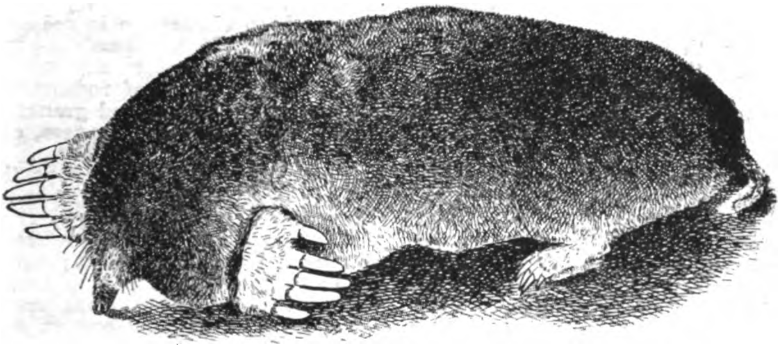
EXPERIMENT STATION.—Bulletin 168.

ED. H. WEBSTER, *Director.*

FARM BULLETIN.

Entomology and Zoology Department.

THOMAS J. HEADLEE, *Entomologist and Zoölogist in Charge.*



THE COMMON MOLE (*Scalops aquaticus*). Original.

The Common Mole.

BY

THEO. H. SCHEFFER, *Assistant in Zoology.*

MANHATTAN, KAN.
AUGUST 1, 1910.
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AGRICULTURAL EXPERIMENT STATION.

Department of Entomology and Zoology.

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G. A. DEAN............	Assistant in Mill and Grain Insect Investigations.
J. B. PARKER..........	Assistant in Field Insect Investigations.
L. M. PEAIRS..........	Assistant in Fruit Insect Investigations.
HARRY EVANS	Assistant in General Entomological Investigations.
THEO. H. SCHEFFER..	Assistant in Zoölogical Investigations.

Work of the Department of Entomology and Zoology.

This department covers a wide field of usefulness to the farmers of Kansas. For two years there has been maintained a general field survey and extensive investigation of the ravages of field insects such as chinch bug, Hessian fly, green bug, corn ear-worm, and other insect pests of general agricultural crops. This work has been carried on in coöperation with farmers in various parts of the state. Instructions for combating these insects have been formulated and are sent to any one on request. Investigations as to the destructive tendencies of rodents are in progress. The eradication of insects in mills, elevators and granaries is being studied and is carried on in coöperation with mill owners, elevator men and farmers.

For three years destruction of San José scale, which is perhaps the most serious of deciduous fruit insects, has been carried forward under the entomological law of 1907 in coöperation with farmers and fruit growers. Plantings over 158 square miles have been examined, scale-infested plantings located, and the owners informed of the dangerous nature of the creature with which they had to deal. Methods by means of which the scale could be killed have been explained and arrangements made to carry out the necessary treatment. About 4000 owners and tenants have been personally visited one or more times. More recently other insects injurious to fruit, such as codling moth and plum curculio, have been taken into consideration, and extensive orchard-spraying experiments are now in progress in various parts of the state.

Bulletins, circulars, and press bulletins reporting progress and results of these studies are being issued from time to time and may be had by writing the Experiment Station.

Other Departments of the Station Are—

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ANIMAL HUSBANDRY...........	ROLAND J. KINZER in charge.
BOTANY..............................	HERBERT F. ROBERTS in charge.
BACTERIOLOGY..................	——— ——— in charge.
CHEMISTRY.........................	JULIUS T. WILLARD in charge.
DAIRY HUSBANDRY.............	——— ——— in charge.
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HORTICULTURE..................	ALBERT DICKENS in charge.
MILLING INDUSTRY.............	LESLIE A. FITZ in charge.
VETERINARY SCIENCE..........	F. S. SCHOENLEBER in charge.

THE COMMON MOLE.

By THEO. H. SCHEFFER.

SUMMARY.

1. There seems to be but a single species of mole in Kansas. It is common in the eastern half of the state and abundant in the eastern third. In western Kansas the mole is entirely absent or found only occasionally along the watercourses.

2. The mole is not a social animal, being condemned to a solitary existence by the conditions under which he lives. Moles come out of the seclusion of their underground burrows only occasionally, as if by accident.

3. The mole's system of runways threads the soil everywhere in well watered regions. There are two parts to the system—the deeper burrows or highways leading to small underground chambers, and the shallow surface ridges ranging over the hunting grounds.

4. The mole thrives best in a loose, moist soil abounding in grubs and earthworms. It therefore frequents fields and woods shaded by vegetation, but is not able to maintain existence in the hard, compact soil of semiarid regions.

5. The mole does not hibernate, but is more or less active at all seasons of the year. During the rainy periods of summer his work is pushed the most vigorously.

6. The young of the mole are produced within a period of three to five weeks, mainly in March and early April. They number from three to five.

7. The labyrinth of tunnels constructed by the mole serves as passageways for several species of mice, which are alone responsible for most of the damage to seeds, roots, and tubers encountered in the soil.

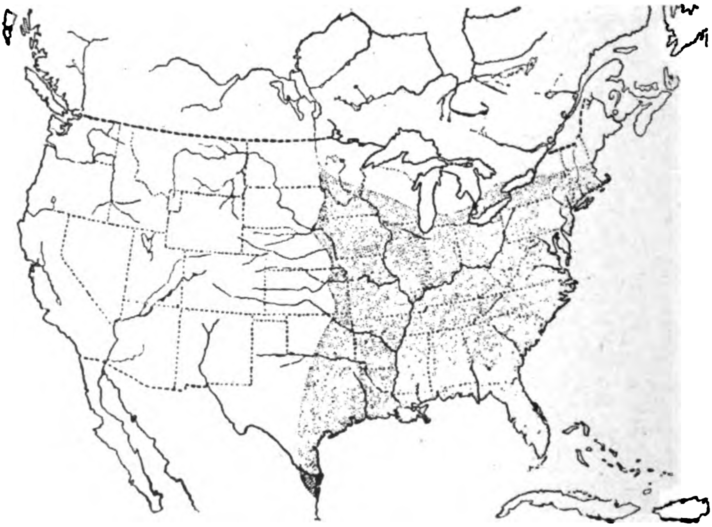
8. The diet of moles consists almost exclusively of the various insects, grubs and worms to be found in the soil. The amount of vegetable substance found in stomach examinations is usually no more than might have been taken in incidental to the ingestion of other food.

9. By reason of its secluded life underground, the mole has but few natural enemies. Coyotes, badgers and skunks dig out a few of them, and occasionally a hawk or owl surprises one aboveground. The flooding of lowlands during spring freshets is probably the greatest danger that menaces the adult mole and his progeny.

10. From the standpoint of food habits, and also in respect to tunneling the soil, the work of the mole is highly beneficial to the interests of agriculture. Moles should not be tolerated, however, in lawns, small garden plats and parks, because of the disfigurement and the injury to plant roots that result from their work.

11. The best method of combating the mole is by means of a trap in the hands of a person who knows how to set it. Crystals of strychnine in raisins or bits of fresh meat make fairly effective poison baits.

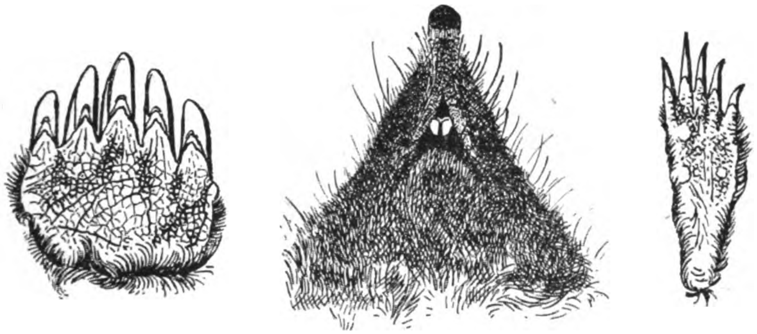
12. The mice which take seed corn in the ground may be destroyed by introducing poisoned grain baits into mole runways throughout the field. The theft of seed corn may sometimes be prevented by treating it with coal tar, tobacco decoction, or stock dip before planting.



Geographical distribution of the common mole (genus *Scalops*), shown by the shaded area. (From True's Revision of American Moles.)

DESCRIPTION AND DISTRIBUTION.

The mole which forms the subject of this discussion is usually referred to as the "common garden mole." It belongs to a genus (*Scalops*) which is distributed very generally over the eastern part of the United States and the Mississippi valley as far west as the plains. There is not enough variation in type over this range to establish more than a single species (*aquaticus*), but four or five subspecies are recognized. The Kansas mole has usually been assigned to the subspecies *machrinus*, but from the large number of specimens examined it seems best to place it in the subspecies *intermedius* of Elliott. Therefore it may be designated as *Scalops aquaticus intermedius*.



Hand, nose and foot of the common mole; under surface in each case. Original.

The true moles may be distinguished from meadow mice, shrews, or pocket gophers—with which they are often confused—by the following peculiarities: They have a naked, pointed snout extending nearly a half inch in front of the mouth opening, which is, therefore, ventral. The eyes are very minute and concealed in the fur. The same is true of the auditory orifice. There are no external ears. The fore feet are very large and broad, the palms being wider than long. The toes of the feet are webbed to the base of the claws, which are broad and depressed. The hind feet are small and narrow, with slender, sharp claws. The variation in size among individuals taken in the same locality is not especially marked, but it is more noticeable when comparing specimens taken in arid and in moist regions respectively.

The following data apply to the first 100 moles taken at Manhattan during the progress of these experiments:

AVERAGE DIMENSIONS AND WEIGHT.

Males (45 specimens):
- Average total length, 176 mm. (about 7 inches).
- Average length of tail, 30 mm. (about $1\frac{3}{16}$ inches).
- Average weight, 4 ounces.

Females (55 specimens):
- Average total length, 168 mm. (about $6\frac{5}{8}$ inches).
- Average length of tail, 30 mm. (about $1\frac{3}{16}$ inches).
- Average weight, 3 ounces.

In contrast to the slight variation in size among moles taken in the same locality is the marked variation in color. The dominant shade is a mingling of lead color and brown, but some specimens are darker than this and, on the other hand, some are a beautiful slivery gray, or perhaps are tinged with purplish. At least two were taken that were suffused all over with rich golden brown. On the average about one-half of the moles taken here have certain regions of the body—particularly the nose, chin and breast—washed with a tinge of orange or have distinct patches of this color on the head or belly. Some of these patches are yellowish or golden brown instead of orange, and occasionally one is nearly white. A common marking is a band on the nose. The patches vary in size from a mere streak to a blotch covering almost the entire area of the belly or head. The following data on color markings are from the same 100 moles discussed under the head of average dimensions and weight:

Males:	
Number having orange or rusty brown markings	27
Number marked on nose only	5
Number suffused or washed in part	18
Number having well-defined patches	6
Females:	
Number having orange or rusty brown markings	23
Number marked on nose only	12
Number suffused or washed in part	2
Number having well-defined patches	9

The distribution of moles seems to depend very largely upon the humidity of the climate and consequent condition of the soil in any particular region. As will be shown later, the mole thrives best in a loose, moist soil, abounding in grubs and earthworms. The hard, compact surface earth of arid and semiarid regions is not at all inviting to an animal that must make its living by plowing along beneath the feet of the more favored creatures that crop the grass. Though able, perhaps, to burrow wherever an earthworm can burrow, the mole could not thrive and maintain its numbers in regions where these worms were few and small in size.

The accompanynig map (page 2) gives the distribution of the genus *Scalops*. Two other genera—*Condylura* and *Parascalops*—occupy portions of this same territory. Between the shaded area on the map and a narrow strip bordering the Pacific coast there are said to be no moles. This statement must be taken with some reservation, however, for moles are found in decreasing numbers on the lowlands along the watercourses as far west at least as the one hundred and first meridian. On a recent trip through the western part of Kansas, careful search was made for evidences of moles in favorable spots along the Saline, the Smoky Hill and the Arkansas rivers and their tributaries. At Wilson, on the Saline, moles were fairly common in cultivated fields and gardens. They were also reported from the Station grounds at Hays. At Oakley, no traces of the animal could be found, nor did inquiry among the residents show that one had ever been seen there. Along the Smoky Hill it was learned that moles have been taken occasionally as far west as Logan county, but no traces of their work were found. Residents along the river at Wallace assert that there are no moles in the country. At Garden City, on the Arkansas, moles were sufficiently numerous to be troublesome in lawns. A specimen taken at Great Bend did not seem to differ in any respect from those collected at Manhattan.

ACTIVE PERIODS.

WET AND DRY PERIODS. The mole does not hibernate. Like the pocket gopher, he is more or less active at all seasons of the year. It is during the rainy periods, however, when the soil is moist quite to the surface, that his work is pushed the most vigorously. Shallow runways are then rapidly extended in all directions, and old runways repaired. When, later, the ground becomes dry and hard, extensions to the system of tunnels are made only in shaded spots, in cultivated fields, or in other favored areas where for some reason or other the soil has become less compact. When a mole chooses to go in a certain direction, however, nothing but concrete or stone will stop him. The strength of the little animals is marvelous. They will heave up the surface of a path trodden so hard that repeated blows of a pick would be required to break the crust. In like manner the bricks of a sidewalk are pushed up out of place, and on one occasion a run was noticed heaved up across the hard, baked roadway over which a heavy traction engine frequently passed.

THE FALL SEASON. In the late fall one will observe an increasing number of the little mounds of earth often associated with a system of mole runways. The presence of these indicates active operations in some of the deeper parts of the system. Ordinarily a mole makes his way through the soil much as a root does, or a stake when driven by the blows of a sledge. The earth is not excavated, but simply crowded aside. This is true of the work even at considerable depths when the soil is moist. But when the ground becomes harder, as it usually does in the autumn, the mole is obliged to excavate the passageways with his stout front feet and dispose of the loose earth by pushing it out through openings in the roof of his surface tunnels.

IN WINTER. At any time in winter when the ground is not frozen too hard, the mole keeps up his work. During the freezing days of January observations have shown fresh burrows ridging up a hard crust of snow covering a thin layer of frozen soil. There seems to be no good reason for assuming, as some do, that during hard freezing weather the mole keeps burrowing away beneath the frost line. He could not make his way at this depth by compacting the soil, and observations have not shown loose earth brought to the surface at such times. Again there would be no need to carry on burrowing operations under such unfavorable conditions. The system of passages already constructed could be retraversed in search of food until opportunity offered for extending it. Worms and hibernating insects are just as likely to be found in a passageway the second or third time it is traversed as they were when it was being constructed, for many of these little creatures of the soil are on the move also.

FOOD STORAGE. Owing to the peculiar character of a mole's diet, storage of food for an unfavorable period or season would seem out of the question. There seems to be no indications that supplies are thus laid up for a "rainy day." A

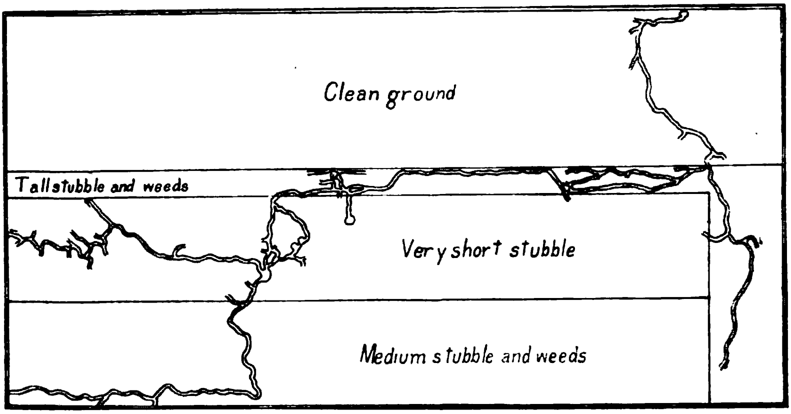
French writer avers that the common European mole stores earthworms, first biting off their heads so they cannot escape. Such a trifling thing as the loss of a head would not hinder our American earthworms from making their escape tail first.

WORKING HOURS OF THE DAY. It seems to be a matter of common observation that the mole can be found at work more frequently in the morning and evening than at any other time of day. Some observers also state that there is a third period of activity, between eleven and twelve o'clock, noon. This statement has not been verified by these observations.

HABITS.

GENERAL. Like the various species of pocket gophers that inhabit the prairies and plains, the mole lives in the seclusion of underground burrows, coming to the surface only by accident. He does not even permit himself the diversion of an airing at the mouth of an open burrow, as does the gopher when he comes out at dawn or twilight with load after load of fresh earth from his excavations. When the mole has occasion to dispose of any surplus dirt he simply pushes it up from beneath until it forms a loose pile with radiating cracks, unlike the dump formed coal-pit fashion by the pocket gopher. Living thus in darkness, removed from the sights and sounds that attend the lives of insects, birds and mammals above him, the round of his experiences consists mainly of the smells of fresh moist earth, of plant roots, and of the various worms and grubs he seeks out for food. He feels also the jar of passing feet, the trickle of percolating waters after a shower and the changes in temperature as the seasons come and go. Observations have led us to believe that the mole is not a social animal —that the very character of his environment compels him to lead the life of a hermit. This must necessarily be the case with any animal that spends all of its time underground. It is true that on several occasions two or even three moles have been trapped at the same spot, but that need not lead to the inference that they had lived together in a social way in that particular burrow. In soil ridged up by a labyrinth of runways frequent intersections of separate burrows must necessarily result.

THE RUNWAY. After following along the devious course of a mole's path, just beneath the surface of the ground, one will find sooner or later that it begins to run slightly deeper in a certain direction. Approaching from another quarter of the infested plat the surface runway will again be found to turn downward somewhere in the same direction as before. These deeper runs are the highways leading from the mole's home to his hunting grounds. In fact, they may be said to constitute a part of his permanent residence, although the home proper is an irregular chamber here and there connected with these runs. The latter follow a course from five to seven or eight inches beneath the surface of the ground—deeper than the soil is usually stirred by agricultural operations. The chambers from which these runs radiate are not large, their average capacity being about a quart. These investigations have never revealed any nesting material in them. The American genera of moles do not construct "mole hills," as the European genus *Talpa* is said to do.



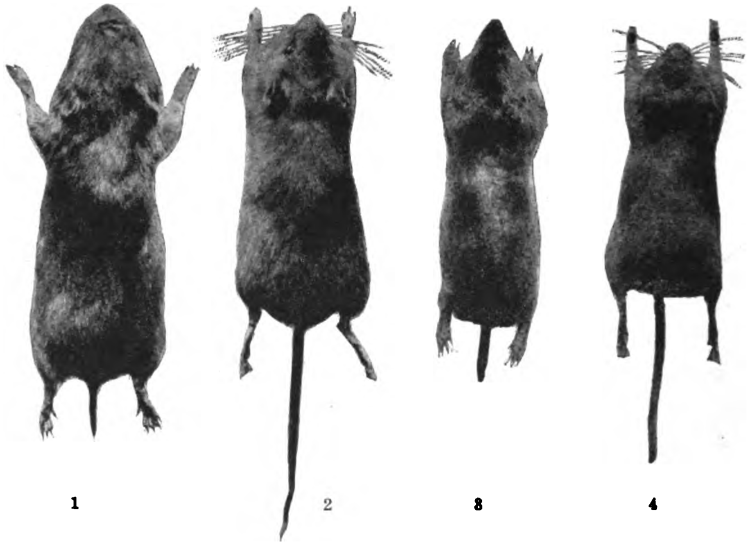
Plot of ground in which a mole runway was excavated. The total length of the parts of the runway shown was 475 feet. The deeper parts of the runway are just to the left of the center of the illustration. Several small chambers were found in this part of the system.

By far the greater extent of a mole's system of runways is made up of the shallow burrows ranging over his hunting grounds. These are merely subsurface paths pushed hither and thither by the vigorous little animal in his search for food. They may not be used again or they may be retraversed at irregular intervals. After a time they become filled up by the settling of the soil above, especially after heavy showers. In some cases, also, the mole evidently pushes into them the dirt which he has excavated in his deeper runways. These subterannean hunting paths are about an inch and a quarter to an inch and a half in diameter. They usually ridge up the surface of the soil so that their course can be readily followed. In wet weather they are very shallow; during a dry period they range somewhat deeper, following the course of the earthworm.

HABITAT. While the mole seeks out the higher and dryer spots for his home and his highways, he hunts preferably in soil that is shaded, cool and moist. Here worms and grubs abound, and these favored areas soon become traversed by a perfect labyrinth of subsurface paths. This accounts for the persistency with which moles stick to our lawns and parks. In neglected orchards and natural wood-lands, where the mole works undisturbed, the ground yields everywhere to the tread, giving evidence of the presence of runways under the leaves or matted grass. In the vicinity of buildings or sidewalks the mole very commonly makes his headquarters under portions of these structures.

Persistent as the spider in repairing its web when torn by accident or design, the mole patiently labors to reconstruct his principal runways when gullied by heavy rains or otherwise damaged. His invariable practice is to burrow under and heave up the floor of the old run wherever the roof has fallen in, thus forming a new passageway beneath. He will repeat this process time after time when one opens up his burrows by hand, until the most recent effort at tunneling and repairing will have taken him down beneath the floor of a narrow trench as much as a foot in depth.

THE MOLE'S GUESTS. Whether willing or not, the mole finds himself compelled to act as host to a large number of guests that throng his hallways. The maze of passages that thread the soil everywhere furnishes concealment and lines of traffic to several species of small mammals not favored by nature with the means for digging runways of their own. What the mole's attitude towards each species of these intruders may be these investigations have not revealed. In the case of the shrew it would seem to be one of hostility, for the shrew and the mole are on the lookout for the same kinds of food. The shrew is generally supposed to do some burrowing on his own account, but any number of the little animals have been trapped in runways that from their size and general appearance were undoubtedly constructed by moles. In fact, observations more than once showed a trap holding a dead shrew pushed up by fresh mole work almost out of the small excavation that had been made. Whether tolerated or not, the shrew by no act contributes to blackening the reputation of his host as do the other guests—mainly voles (meadow mice), white-footed field mice and the common house mouse. These latter are directly responsible for most of the thefts of grains, seeds and tubers commonly laid to the charge of the mole. Conclusive evidence of the truth of this statement will be found in another part of this bulletin. It is sufficient to state here that the presence of these little rodent pests in considerable numbers in the mole's runways can easily be demonstrated by the use of small traps.



The Mole's Guests. (Original.) 1—Meadow mouse (*Microtus*). 2—White-footed mouse (*Peromyscus*). 3—Shrew (*Blarina*). 4—Common house mouse (*Mus musculus*).

Breeding. Though one of the most abundant of our small mammals, the mole is a slow breeder. This would be expected of an animal withdrawn from the strife and competition that reddens tooth and claw in the world above his secluded burrows. As will be seen from the accompanying table, the number of young at a birth is normally four and but one litter is produced annually. These facts were ascertained from the examination of a large number of females (101) taken in all months of the year. Thirty-three of these were either pregnant or gave indisputable evidence of having recently born their young. The first specimen of this latter number was trapped February 27, the last April 20.

It would appear, then, that in this vicinity (Manhattan) the young are produced within a period of three to five weeks, mainly in March and early April. The period of gestation must be comparatively short, for signs of pregnancy did not appear until about five weeks before the first females gave evidence of having borne their young. My data on this point are not full enough to warrant a positive conclusion; for, of the twenty-five moles trapped during the months of December and January, and up to February 27, only five were females. This fact itself may be significant of a period of seclusion or less activity among the females during the period of pregnancy.

While, as stated above, the normal number of young is four, there were two cases in which there was but a single fœtus in one horn of the uterus; the other horn contained two, as usual. In one instance also there were five fœti.

That development after birth is very rapid is shown by the litter of young moles referred to in the last item in the accompanying table. These were discovered in a nest of dry grass under some sod, April 22. The sod had been turned over by the plow only about ten days previously. Although still perfectly hairless, these young moles weighed one ounce each—from one-fourth to one-third the weight of the adult.

Results of the Examination of 38 Female Moles for Breeding Conditions.

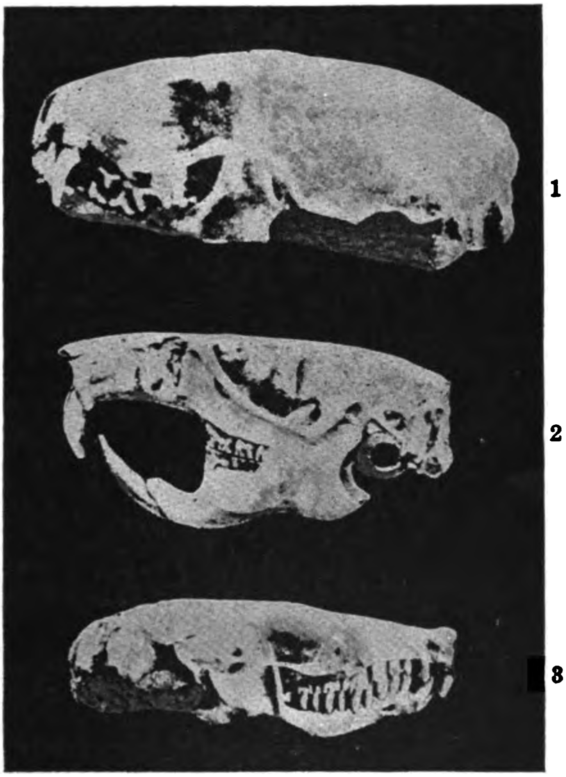
Date.	Conditions for breeding, number of embryos, etc.
Dec. 11,	No signs of pregnancy.
Dec. 17,	No signs of pregnancy.
Feb. 6,	No signs of pregnancy.
Feb. 20,	No signs of pregnancy.
Feb. 22,	No signs of pregnancy.
Feb. 27,	Uterus congested; very evidently pregnant.
Feb. 27,	Uterus very much congested, but fœti not distinguishable.
Feb. 27,	Uterus very much congested, but fœti not distinguishable.
Mar. 6,	Uterus very much congested, but fœti not distinguishable.
Mar. 7,	Three fœti in one horn of uterus, two in the other; scarcely distinguishable.
Mar. 8,	Pregnant. Number of fœti apparently four; scarcely distinguishable.
Mar. 8,	Two fœti in each horn of the uterus; very small.
Mar. 8,	Pregnant, but number of fœti not distinguishable.
Mar. 18,	Pregnant, but number of fœti not distinguishable.

Date.	Conditions for breeding, number of embryos, etc.
Mar. 22,	Pregnant, but number of fœti not distinguishable.
Mar. 26,	Pregnant, but number of fœti not distinguishable.
Mar. 29,	Pregnant, but number of fœti not distinguishable.
Mar. 30,	Two fœti in each horn of uterus; about as large as navy bean.
Mar. 30,	Two fœti in each horn of uterus; about as large as navy bean.
Apr. 1,	Two fœti in each horn of uterus; a little smaller than the above.
Apr. 2,	One fœtus in right horn of uterus, two in left; size of hulled peanut.
Apr. 8,	Indications that the young had been recently born.
Apr. 9,	Two fœti in each horn of uterus; size of navy bean.
Apr. 10,	Indications that young had been recently born; milk in glands.
Apr. 11,	Three fœti; size of small navy bean.
Apr. 13,	Four fœti, very small but easily distinguishable.
Apr. 13,	Young evidently recently born; uterus flabby and veins congested.
Apr. 14,	Young evidently recently born; number of fœti had been four.
Apr. 14,	Young evidently recently born; number of fœti had been four.
Apr. 14,	Young evidently recently born; number of fœti had been four.
Apr. 15,	Young born; evidences of being suckled.
Apr. 16,	Young evidently born.
Apr. 17,	Young born. Number of fœti had been four.
Apr. 17,	Young evidently born.
Apr. 19,	Young evidently born.
Apr. 20,	Young evidently born.
Apr. 20,	Young evidently born.
Apr. 22,	Four young moles taken in nest; weighed one ounce each.

SUMMARY.

Number of females pregnant or having recently borne young	33
Normal number of young, apparently	4
Largest number of young in any case	5
Smallest number of young in any case	3
Number of cases in which fœti were distinguishable	10
Cases in which condition of uterus indicated number of young recently born	4
Nests of young moles	1
Cases of 4 fœti	12
Cases of 3 fœti	2
Cases of 5 fœti	1

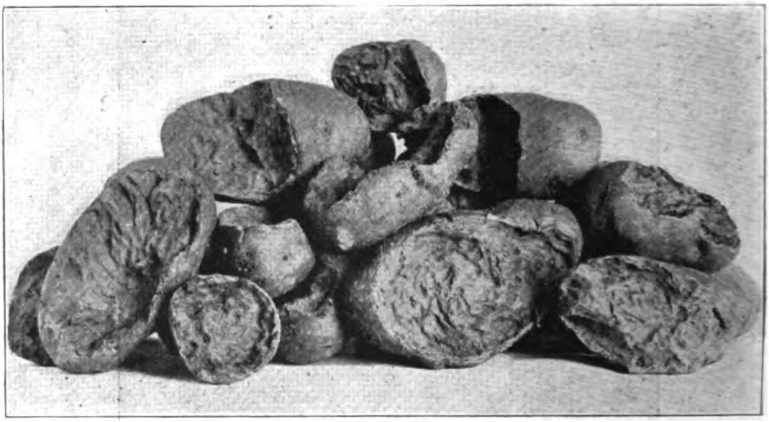
FOOD. The moles and the shrews constitute the sole representatives in North America of the mammalian order Insectivora (insect-eaters). A study of their dentition, the character of their food, and their general behavior in several respects, shows that they are much more closely related to the carnivorous or flesh-eating mammals than to the rodents, a group which includes the rats, mice, rabbits, squirrels and the like. This is especially true of the shrews, which are quite weasel-like in character. They fight savagely, kill and eat other small mammals larger than themselves, and when angry or excited emit a musky odor like the weasel and the mink.



Comparative dentition of a carnivore, a rodent, and a mole. (Adapted from D. G. Elliot.) 1—Skull of a weasel (*Putorius*). 2—Skull of a wood-rat (*Neotoma*). 3—Skull of a mole (*Scalops*).

It has long been known to scientists, through careful study and investigation, that the diet of moles consists mainly of the insects, grubs and worms to be found in the soil. This fact, however, has been slower in gaining popular credence than most scientific pronunciamentos. In another part of this bulletin the mole's guests have been called to account for the general prejudice which has arisen against him, and, again, in this connection, let it be understood that the mole is directly responsible for only a very small portion of any damage to seeds, grains and tubers in the ground. Field mice, voles and the common house mice are the guilty parties. If anyone is skeptical on this point he has only to set a few small mouse traps, properly baited, in the mole's runways and await results. In setting the trap a small excavation should be made with a knife or trowel. Place the trap on a level with the bottom of the runway. See that the latter is open both ways, and cover the excavation with a board or piece of sod to exclude the light and prevent the entrance of any small animal except by way of the burrow. Try various baits, such as soaked corn or peas, bits of meat, insects, and pieces of potato.

With respect to damage to roots and tubers by eating into them, it will usually be found on careful examination that the tooth marks are those of rodents.



Potatoes gnawed by rodents following in mole runways. Original.

EXAMINATION OF STOMACH CONTENT. Direct evidence of what an animal eats may usually be obtained in one or all of three ways: By examination of stomach contents, by observations in the field, and by experiments with captives. In the case of the mole field observations are of course impracticable. By the other two methods, therefore, we have endeavored to satisfy ourselves, and, we hope, others, as to the character of a mole's diet. The accompanying table gives the results of the careful examination of the stomach contents of 100 moles.

Results of Examination of 100 Moles' Stomachs.

Serial number.	STOMACH CONTENTS.
1	7 white grubs, 20 ants, 2 centipedes, 1 wasp.
2	2 white grubs, 1 earthworm, 1 beetle.
3	3 white grubs, 2 earthworms, 5 Diptera, beetle fragments.
4	8 white grubs, 3 larvæ (cutworms?), 1 beetle, plant rootlets.
5	2 white grubs, beetle fragments, 1 insect larva, plant fibers.
6	2 earthworms, 1 May beetle, 1 plant rootlet.
7	2 white grubs, 1 beetle larva, plant fibers.
8	5 white grubs, 5 beetle larvæ, 1 earthworm, 3 other larvæ, 1 cricket, fragments of vegetable tissue.
9	2 earthworms, 2 white grubs, 2 larvæ, 1 beetle, plant fibers.
10	15 white grubs (small), insect fragments.
11	5 earthworms, 1 white grub, 1 centipede, 1 fly, 1 cricket, 1 puparium, insect fragments.
12	2 earthworms, 18 ants, 1 beetle larva.
13	3 earthworms, 17 ants, 2 puparia, insect fragments, plant fibers.
14	2 white grubs, 2 beetles.
15	2 white grubs, 1 beetle larva, 2 beetles, 1 cricket, 1 ant, 3 centipedes.
16	2 earthworms, 3 insect cocoons, insect fragments.
17	8 earthworms, 19 white grubs, plant fibers.
18	1 earthworm, 1 puparium, 1 spider, 1 larva, plant fibers.
19	1 white grub, 1 earthworm, 1 centipede, 328 ants, 3 beetles, 1 tree cricket, plant fibers.
20	4 earthworms, 1 May beetle, 1 tiger beetle, 10 puparia, 2 beetle larvæ, 2 other larvæ.
21	1 beetle, 20 ants, 1 earthworm, insect fragments.
22	1 white grub, 3 cocoons, 6 larvæ, 1 beetle (Carabid), 1 beetle (Scarabid), plant fibers.
23	3 earthworms, 2 white grubs, 2 centipedes, 5 ants, 1 May beetle, 1 other beetle, 1 beetle larva.
24	1 earthworm, 1 centipede, 30 ants, 2 beetles, 1 beetle larva.
25	19 puparia, 1 earthworm, 16 ants, 1 beetle.
26	5 earthworms, 6 puparia, 2 beetles.
27	4 centipedes, 2 white grubs, 4 beetles, 5 beetle larvæ.
28	1 centipede, 2 beetle larvæ, insect fragments.
29	1 white grub, 2 ants, 1 beetle, insect fragments.
30	2 white grubs, 1 spider, 1 beetle, 1 May beetle, plant fibers.
31	1 beetle (Chrysomelid), 1 cocoon, 1 puparium, fragments of plant tissue.
32	1 white grub, 1 spider, 1 centipede, insect fragments, fragments of plant tissue.
33	1 May beetle, 1 ant, 1 beetle.
34	1 white grub, 82 ant puparia, 3 ants, 1 beetle, 1 beetle larva.
35	2 white grubs, 1 spider, 1 beetle larva, insect fragments.
36	1 white grub, 7 puparia, 1 centipede, 1 ant, 1 bug, 1 grasshopper, 1 May beetle, 1 tiger beetle.

Serial number.	Stomach Contents.
37	1 earthworm, 1 white grub.
38	1 beetle (Carabid), 2 white grubs, 2 larvæ, 1 beetle larva.
39	4 earthworms, 1 white grub, 10 cocoons, 1 centipede, 1 beetle (Carabid), 21 larvæ.
40	6 white grubs, 1 beetle, fragments of plant rootlets.
41	1 white grub, 1 cocoon.
42	2 beetle larvæ, 2 earthworms, several plant fibers and rootlets.
43	6 beetles, 3 beetle larvæ, 1 white grub, 1 spider.
44	1 beetle larva, 1 pupa, 1 white grub, 1 beetle, 1 earthworm.
45	4 earthworms.
46	3 earthworms, 15 small beetle larvæ, 1 white grub, 1 beetle, fragments of plant tissue.
47	1 white grub, insect fragments, 1 seed husk.
48	12 earthworms, 1 beetle larva, 2 white grubs.
49	4 white grubs, 2 earthworms, 1 ant, 1 bug, 1 cocoon, a few plant fibers.
50	3 white grubs, beetle fragments, a few bits of plant fiber.
51	4 earthworms, 1 white grub, 6 beetle larvæ, 1 wasp, fragments of plant tissue.
52	2 white grubs, 1 spider, 1 larva, insect fragments.
53	4 earthworms, 3 white grubs, 2 beetle larvæ, 1 cricket, 1 centipede, a few plant fibers.
54	5 white grubs, 1 earthworm, 15 beetle larvæ, 1 beetle, 1 cocoon of eggs, plant fibers.
55	6 earthworms, 7 white grubs, 2 beetle larvæ, 1 beetle.
56	6 white grubs, 1 earthworm, 1 beetle larva, insect fragments, fragments of plant tissue.
57	14 white grubs, 2 beetle larvæ, 2 beetles, 20 small larvæ.
58	2 white grubs, 2 wasps, 1 beetle, 1 beetle larva, insect fragments, 1 seed pod.
59	5 white grubs, 2 wireworms, 1 cricket, 1 wasp, 1 beetle, 3 beetle larvæ, 7 puparia.
60	4 white grubs, 2 earthworms, 1 beetle, 1 centipede, 1 spider.
61	12 white grubs, 2 earthworms, 2 beetle larvæ, 1 beetle, a few bits of plant tissue.
62	26 white grubs, 4 wireworms, 2 beetles, 1 centipede, 1 beetle larva.
63	2 puparia, 2 white grubs, 2 beetles, 3 centipedes, 2 beetle larvæ.
64	4 white grubs, 1 beetle, 1 beetle larva.
65	2 earthworms, 2 beetle larvæ, 1 beetle.
66	3 earthworms, 3 centipedes, 1 beetle, 1 puparium, 2 seed husks.
67	3 centipedes, 4 beetle larvæ, 2 beetles, 1 spider, 1 bit of plant tissue.
68	7 white grubs, 1 earthworm, 1 spider, 1 wasp, 1 beetle larva, 1 beetle, bits of plant tissue.
69	3 spiders, 1 beetle, 1 beetle larva, 1 plant rootlet.
70	171 small white grubs, 3 large white grubs, 1 May beetle, 1 beetle larva, 2 plant rootlets.
71	55 small white grubs, 1 grasshopper.

Serial number.	STOMACH CONTENTS.
72	Several spiders, 8 beetle larvæ, 1 earthworm, 1 wasp, fragments of several beetles.
73	3 beetles, 1 earthworm, 1 cocoon, 1 wasp, 3 beetle larvæ, skin of seed or root.
74	1 cocoon, 1 spider, 1 cricket, 1 earthworm, 1 beetle larva, 1 beetle, a few plant fibers.
75	4 earthworms, 8 puparia, 1 beetle, 1 cricket, 1 beetle larva, skin of seed or root.
76	1 earthworm, 1 spider, 1 May beetle, a few plant fibers.
77	1 earthworm, 7 beetle larvæ, 1 beetle, miscellaneous insect fragments.
78	3 beetles, 1 bug, 1 beetle larva, 1 white grub, insect fragments.
79	4 white grubs, 1 spider, 1 beetle, 2 beetle larvæ, a few plant fibers.
80	12 white grubs, 1 seed husk, a few plant rootlets.
81	44 insect larvæ, 1 beetle.
82	73 white grubs, 4 cutworms, 1 beetle, 1 larva, 1 seed husk, a few plant fibers.
83	1 earthworm, 2 spiders, 3 beetles, 1 cricket.
84	250 ant puparia, 2 beetle larvæ, 2 spiders, 2 beetles, a few plant rootlets.
85	3 earthworms, 1 spider, 8 puparia, 2 beetle larvæ, 1 beetle.
86	205 ants, 4 white grubs, 38 cutworms, 2 beetles, 1 spider, plant fibers.
87	2 earthworms, 1 puparium, 5 white grubs, 1 spider.
88	12 insect larvæ, 58 ants, 4 spiders, 1 hairworm (*Gordius*), 3 beetles.
89	3 cutworms, 60 ants, 1 beetle, 2 earthworms, skin of seed or root.
90	1 earthworm, 1 centipede, 18 puparia, 1 beetle.
91	10 cutworms, 1 spider, 1 beetle, insect fragments.
92	5 white grubs, 3 centipedes, 1 puparium, 1 cricket, 4 cutworms, a few plant fibers.
93	1 earthworm, 1 white grub, 3 larvæ, skin of seed or root, a few plant fibers.
94	2 centipedes, 5 cutworms, 1 spider, 2 larvæ, skin of seed or root.
95	2 centipedes, 1 puparium, comminuted mass of insect and centipede fragments.
96	3 white grubs, 1 larva, 1 centipede, 1 beetle, skin of grain or root.
97	4 white grubs, 1 cutworm, 1 ant, insect fragments, a few plant rootlets.
98	3 earthworms, 2 centipedes, 3 larvæ, 1 spider, 1 beetle, 1 puparium.
99	2 earthworms, 1 white grub, 2 centipedes, insect fragments.
100	1 white grub, 2 centipedes, 8 ants, mass of beetle fragments.

SUMMARY OF TABLE.

White grubs	64	stomachs
Earthworms	49	“
Beetles	67	“
Beetle larvæ	44	“
Other larvæ	25	“
Centipedes	25	“

Ants	19	stomachs
Wasps	7	"
Flies	2	"
Plant fibers and rootlets	43	"
Seed pods or husks	8	"
Crickets	10	"
Insect fragments	31	"
Puparia	21	"
Cocoons	10	"
Spiders	23	"
Grasshoppers	2	"
Bugs	3	"
Skin of grain or roots	6	"
Hair-worm	1	"
Number of stomachs infested by parasitic threadworms		28

In the course of the two years' investigations concerning the ways of the mole about 200 specimens have been checked up on our field notes. From this number the hundred individuals given above were selected so as to include some from each month of the year and to exclude any whose stomachs were empty or nearly so. The selections had no reference to stomach content, however, for they were made before examination of the latter.

The proportions of the various articles of food do not vary with the season as they do in the case of birds, for in some form the insects, worms and grubs listed in the above table are about as abundant in the soil at one time of the year as at another. It is scarcely necessary to add, however, that these supplies are not always equally accessible. In the summer when the soil is wet with recent rains the mole plows along very near the surface, extending his runways rapidly and gathering in a harvest of insects and worms, some of which have also come nearer the surface under these conditions. In dry periods or during portions of the winter season the mole must range deeper, for his prey has likewise found retreat farther down in the soil.

No attempt has been made to compute the actual percentages of each article of food in the list of twenty or more kinds given in the table. Such figures would be mere approximations at best. The end in view in the examination of each stomach was to discover what kind of creatures or substances it contained and, by noting repetition of similar parts of these organisms, how many of each kind.

While plant fibers or rootlets show up in forty-three cases, *in no case was the amount of identifiable plant tissue more than might have been taken in incidental to the ingestion of other food.* In many of the stomachs there was a considerable residue after repeated washings, filterings and eliminations of identifiable substances. This residue undoubtedly consisted largely of soil from the intestines of earthworms and finely comminuted animal and, perhaps, plant tissues. Even though starch, sugar or cellulose might be detected by chemical analysis, there would be no means of telling how much of this might have come from the digestive tracts of the insects taken as food.

Six stomachs contained fragments of plant tissue which may have been parts of the seed coat of corn, but resembled very closely thin bark from plant roots.

EXPERIMENTS WITH CAPTIVE MOLES. It is a difficult matter to keep a mole any considerable length of time in captivity. Altogether we have had more than a score under observation for a short time, but seldom have any of them been kept alive for more than a day or two. Either fright and worry, or lack of proper food in sufficient quantity, soon terminated the life of each captive. They have always been kept in tubs or boxes with a layer of earth several inches deep on the bottom. They were supplied with water and with food of several kinds, some of which they would eat readily. One individual survived for nearly two weeks and seemed to grow fat and sleek under the care we gave him. He finally died of too much kindness.

These imprisoned moles had insatiable appetites, eating ravenously bits of beefsteak and large numbers of earthworms. When freshly killed English sparrows were put in the cages in the evening, very little but bones and feathers would be left by morning. All refused to touch corn, potatoes or sweet potatoes, except the individual kept so long. He would eat these articles with some apparent relish, although he went about it very awkwardly. Instead of nibbling at a grain of corn as a rodent does, he would crowd it against the ground with his cheek and, gaining possession of it, chew it in the side of his mouth much as a steer chews a nubbin. The act or drinking water from a shallow dish was accomplished hog fashion, owing to the considerable projection of his snout beyond the aperture of the mouth.

When he was feeding on earthworms, there was no evidence of any attempt to first strip out the contents of the worm's alimentary canal, as has been reported by one investigator.

NATURAL ENEMIES AND CHECKS.

BIRDS. Probably no mammal on the North American continent has so few natural enemies as the common mole. Since it probably never leaves the darkness of its underground burrows except by accident, it is much less subject to attack by predatory animals than even the pocket gopher and the shrew, whose habits are somewhat similar to those of the mole. The following data gleaned from "Hawks and Owls of the United States," published by the United States Department of Agriculture, substantiates the above statement and shows how little the mole has to fear from the so-called birds of prey:

BIRDS.	No. of stomachs examined.	Remains of common moles.	Remains of shrews.	Remains of pocket gophers.
Red-tailed hawk (*Buteo borealis*)	562	6	46	8
Red-shouldered hawk (*Buteo lineatus*) ..	220	3	40	0
Broad-winged hawk (*Buteo latissimus*),	65	1	16	0
Barred owl (*Syrnium nebulosum*)	109	3	3	0
Barn owl (*Strix pratincola*)	39	0	5	8
Ten other hawks and owls (all that had eaten common moles, shrews, or pocket gophers)	1,131	0	35	14
Totals	....	13	145	30

In the above comparison it should be borne in mind that owls disgorge the pellets of bones and hair shortly after a meal. If to the figures on the pocket gopher in this table should be added the large numbers of those animals whose remains are found about the nests and roosting places of the barn owl and great horned owl, particularly, the total would be swelled enormously. Data on the number of moles and shrews found in similar situations are not at hand, but if their remains were at all conspicuous in the piles of disgorged pellets the matter would have received mention.

MAMMALS. The investigator has known personally of a few cases of keen-scented dogs acquiring the habit of searching out moles in fresh runways. The dog's sense of smell served to locate the mole, which was then pounced upon and speedily brought to the surface. In the files of the *Rural New Yorker* is found a short article by a subscriber in Missouri, who claimed to have several dogs that were adepts at this work.

These dogs, he states, were a cross between a Scotch collie and a prairie wolf, or coyote. This and other evidence at hand goes to show that the coyote, with his stealthy, skulking ways and his inquisitive nose, probably unearths many a luckless mole from the fancied security of his underground burrow. Judging from their general habits, it is probable also that foxes and badgers, and perhaps skunks, occasionally add moles to their bill of fare.

FLOODS. By far the greatest danger that manaces the adult mole and his progeny is the inundation of lowlands by heavy local rains or the waters of streams passing out of their banks. Such flooding of the soil is of comparatively frequent occurrence in the very situations where moles most abound, and probably serves more than all other things combined to check inordinate multiplication of the species. During the progress of the great June floods in 1903 and 1908, in the valleys of the Kansas and the Blue rivers, moles in large numbers could be found along the railroad embankments and in the driftwood that had lodged against the piers of bridges. What percentage of the adults perish under such conditions it is not possible to conjecture, but undoubtedly earlier spring freshets destroy most of the young on the flooded grounds. Certainly many of the adults survive these conditions, for they are good swimmers. On one occasion I captured more than a score in a single drift lodged against some piers. They seemed to be as vigorous and well fed as when taken under ordinary circumstances from surface burrows. This may be partly accounted for by the fact that the drift was full of beetles and other insects also seeking refuge from the water. Farmers and truck growers on the bottom lands have reported that after a flood subsides the moles and pocket gophers are not long in regaining their lost ground.

DAMAGE.

Considered from the standpoint of food habits alone, it has never been shown that the mole affects detrimentally the interests of the farmer and gardener. Indeed, it can be proven that quite the reverse is true. This statement will receive further consideration under the next heading. When, however, the mole is charged with disfiguring lawns and parks, destroying flower beds, tearing up the roots of grasses and making himself a general nuisance in small garden plots, he will have to plead guilty. The evidence against him is abundant and direct.

ECONOMIC STATUS.

In dealing with a mole it is all a question of whether or not that particular individual is out of place. The mole has his place among the forces of nature, and no unimportant role does he play. One of the most abundant of small mammals, his kind has for ages been working over the soil and subsoil in the interests of plant life. Within the limits of his normal range it is almost safe to say that every square yard of arable land is traversed one or more times each season by portions of his extensive runways. A part of this work is visible at the surface, but much of it is not. The hoe, the plow, the cultivator strike into unsuspected burrows everywhere. After a flood has subsided on lowlands the unequal settling at the surface of the ground discloses the fact that the soil is simply honeycombed with the runways of the mole and one or two other burrowing mammals. This tunneling and the shifting of earth particles permits better aeration of the soil and favors the entrance of water from the surface. It also mixes the soil and subsoil, carrying humus farther down and bringing the subsoil nearer the surface, where its elements of plant food may be made available by the agencies at work there. As an offset to this good work of the mole it may be urged that the earthworms, which form a large part of his diet, play a similar part in the economy of nature. This is true; but who knows but that the earthworm, which lives partly upon green vegetation, might become a terrible scourge if the mole were not placed as a check upon its increase. Nature preserves the balance of power very nicely in the animal world.

A large item in the stomach content of moles is made up of white grubs, those scourges of grass and other valuable plant roots. The table of stomach analyses (on pages 17-18) shows that nearly two-thirds of the moles had eaten white grubs. One had performed the astonishing feat of eating 175, another 73, and another 55. For his good work in destroying grubs alone, therefore, the mole deserves much credit. Among the beetles also, and the insect larvæ in general, which form a considerable part of the mole's food, are many forms that are injurious to agriculture. On the other hand, perhaps the bulk of the beetles were of those ground types that are predacious in habit and therefore may be considered either neutral or beneficial. It would be a tedious if not impossible undertaking to attempt to so classify these beetles as to determine the economic status of each individual or lot. In the vast majority of cases the fragmental character of the remains no more than served to distinguish the order. The spiders, centipedes and ants listed in the table may, as far as present knowledge goes, be reckoned as neutral or beneficial in their relation to agricultural interests.

The proportionately large amount of food consumed by a mole in a given time serves also to raise him in the rank of importance as a destroyer of noxious insects and their larvæ. A mole's appetite seems to be insatiable. Experiments with captives show that they will usually eat voraciously as long as they are supplied with food to their liking, often consuming more than their own weight in a day. This is not gluttony, as it is sometimes characterized. The tremendous amount of energy expended in plowing through the resistant soil requires a correspondingly large amount of food to supply that energy. That they must have this food at frequent intervals also is shown by the fact that a mole in captivity usually starves in a few hours unless supplied with nourishment.

The mole is one of nature's forces to be reckoned with by the agriculturist as he would reckon with nitrogen-forming bacteria, the birds that visit his fields and the bees that pollinate his fruit blossoms. If the individual mole is not out of place, mark him down as an asset and proceed accordingly. If he is where we do not want him, we are privileged to set swift death on his track in the form of traps, poison or club. For this reason—that a mole's presence in lawns, small garden plots, parks and cemeteries becomes intolerable—a line of experiments was undertaken to determine the better methods of getting rid of him in such situations. The results of these experiments follow.

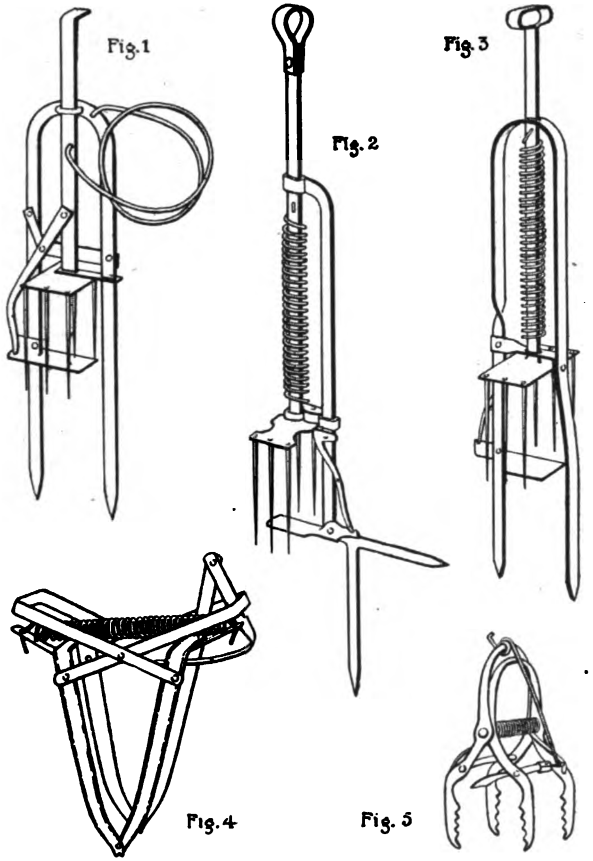
COMBATING THE MOLE.

The mole seems to possess a natural shrewdness and ability to sense danger out of accord with the life of seclusion which it leads. The common rat, from long association with man and hereditary knowledge of poisons and traps, has become proverbial for his sagacity and cunning, but the mole is almost his peer in these respects. This conclusion has been reached after dealing intimately with the mole for a period of two years. Like experience with the pocket gopher, an animal of somewhat similar habits, has demonstrated the fact that in this comparison he is stupidity itself, blundering into any sort of trap laid for him by the wiles of man.

TRAPPING. Trapping is the surest and, so far as my experience goes, the most practical method of getting rid of moles. I make this statement, however, without intention to disparage the utility of other methods. In some of the European countries villages and rural communities have their professional mole catchers, who follow the business for a livelihood. Correspondence with agricultural societies in two or three of these countries elicited the information that these professional catchers commonly use some sort of a trap which they construct themselves. These traps all have as part of their mechanism horse hair or fine wire loops which are drawn tightly about the body of the mole by the release of a pliant stick bent downward when the trigger is set.

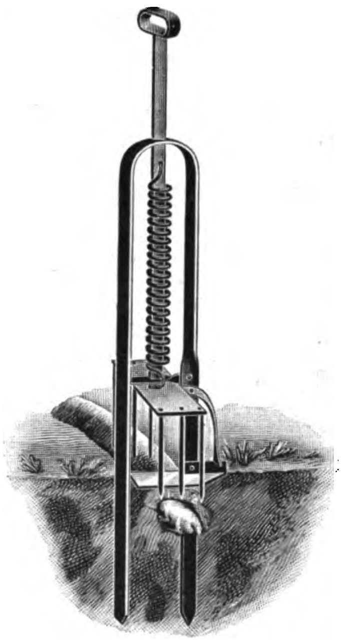
There are a number of excellent mole traps on the market in this country, any one of which, when properly handled, will give good results. All the different makes that have come under my notice depend upon the same sort of mechanism for releasing the spring; namely, a broad trigger-pan intended to be placed directly over a depressed spot in the mole's runway when setting the trap. The raising of this trigger-pan as the mole again upheaves the depressed portion of his surface burrow releases the contrivances designed to kill. The latter are of two types—sharp spikes which impale the mole when driven into the ground by the spring, or two pairs of scissor-like jaws which close firmly across the runway, one pair on either side of the trigger-pan. The arrangement of the spring, the safety catch and other details of individual trap construction are matters of secondary importance.

Plainly the efficiency of any animal trap depends upon its being so constructed as to adapt itself to the habits of the animal it is designed to capture. These mole traps conform to such requirements in at least two particulars—they can be set without exciting the animal's suspicions by entering or introducing anything into its burrow and are sprung by the mole in

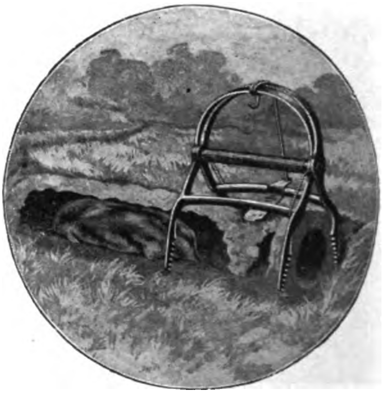


Types of mole traps. 1—The Side-spring trap. 2—The Wherry trap. 3—The Reddick trap. 4—The Chandler (Heartley) trap. 5—The Out o' Sight trap.

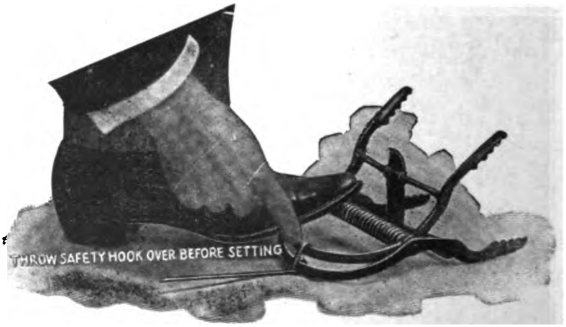
following its natural instinct to reopen its passageways when trodden down by passing feet or otherwise obstructed. Success or failure in the use of these devices depends largely upon the operator's knowledge of the mole's habits and of the machanism of his trap. To set a trap properly one should select a place in the surface runway where there is evidence of fresh work and with the toe of the boot firmly compress the ridge at one spot. If the trap is one of the harpoon or impaling types, raise the spring, set the safety catch and push the supporting spikes into the ground, one on either side of the runway, until the trigger-pan just touches the earth where it was trodden down. Now release the safety catch and allow the impaling spike to be forced down into the ground by the spring. This will facilitate their penetrating into the burrow when the trap is sprung later. Set the trap and leave it, taking care not to tread upon or otherwise disturb any other portion of the mole's runway. In setting the scissor-jawed trap known as the "Chandler" (see illustration, page 25), the points of the jaws are forced directly into the mole's runway until the trigger-pan rests upon the depressed portion as before, and the levers at the top are then pushed apart until the trap is locked. Care should be taken to see that the trap is in line with the mole's runway so that the little animal will have to pass through directly between the jaws. These



The Reddick set on a runway.



The Out o' Sight set on a runway.



Setting the Out o' Sight.

have already cut a path for themselves in the process of being spread apart. Another trap of this type, the "Out o' Sight" (see illustration, page 26), has a very strong spring and must be set by the aid of the foot while resting on a firm surface. It is then secured by a safety hook and its jaws forced into the ground, straddling the runway, until the trigger-pan touches as in the other traps. As the jaws of this trap are rather short it may be necessary sometimes to scrape off some of the grass and dirt on the top of the mole ridge in order to bring the trap down nearer to the actual burrow. Release the safety hook before leaving the trap.

It is useless to attempt the capture of moles by means of small steel traps or the ordinary snap mouse traps set in their runways. This fact became evident in trapping for mice and other guests of the mole. Scores of times the traps were carefully introduced into the burrows and the small excavation covered with sod so as to exclude all light. The results were always the same: scorning the bait or avoiding the unbaited trigger, the mole would plow his way beneath or to one side of the trap and pass on.

POISONING. There are a number of difficulties in the way of getting measurable results in experiments having to do with the poisoning of moles. The method used in conducting these experiments was as follows: A certain number of fresh runways—usually twenty-five—were selected and located by numbered stakes. Into each of these runways the poisoned bait was introduced at three to five different points through small openings made with a lead pencil or sharpened stick of about that size. These openings were then closed with a clod and the exact spot marked by a small pot label. After three or four days a careful inspection of all these locations was made to determine whether or not the bait had been taken or in any way disturbed. The runway was then opened up for a foot or two in each direction from the former location of the bait and left in this condition. In a few days another inspection of the runways was made to ascertain whether the moles were still at work, as would be evidenced by fresh ridging of the earth or by the filling up of that portion of the runway left open as stated above.

Now as to the interpretation of results: If the baits were taken wholly or in part there would be no means of telling whether they were eaten by the mole or by his guests, or even whether the mole had a chance to accept or refuse the bait before it was taken by other occupants of the burrow. The fact that a system of runways showed fresh work after poison had been introduced and the baits taken was, therefore, no evidence that the particular kind of bait was not suitable for the purpose. A mole's system of runways is so extensive that failure to retraverse or work that part of it under observation during the period of the experiment would not be positive evidence that the mole had been destroyed by the poison. Since there is so much intersection of burrows that it is difficult to determine the limits of each individual mole's system of runways, continued activity in the vicinity of a spot where poison had been put out would prove nothing more than that there was at least one mole alive there yet. The summary of more than a thousand records of poisoning operations show that but one dead mole was found.

In all poison experiments strychnia sulphate was used. Various baits were tried, with the following results and conclusions:

Peas. Peas were soaked for forty-eight hours in a solution of one-eighth ounce of strychnia in one quart of soft hot water. Seventy-eight per cent of the baits were taken, probably largely by mice, as sixty per cent of the runways continued to be worked by moles. This is undoubtedly an efficient bait for destroying the mice that follow the mole's runways in newly planted cornfields.

Fresh meat. Small bits of beefsteak were poisoned by inserting a crystal or two of strychnia into small slits made in the bait with the point of a penknife. About the same per cent of baits was taken as in the case of the peas, but a few of them were dug up from the surface. There is, therefore, danger of poisoning such keen-scented animals as dogs and cats by the use of these meat baits. Forty-two per cent of the runways treated showed fresh work after the close of the experiment.

Grasshoppers. The bodies of grasshoppers were poisoned in the same manner as the fresh-meat baits, the heads of the insects having first been pulled off. Sixty-one per cent of the baits were taken, but forty-four per cent of the runways continued to be worked.

Raisins. Raisins were poisoned by removing the seeds and inserting crystals of strychnia. About sixty per cent of these raisins were taken, but they proved to be the most efficient bait tried. Thirty-six per cent of the runways still showed fresh work, however. This bait is recommended by the department of botany of the Michigan State Agricultural College.

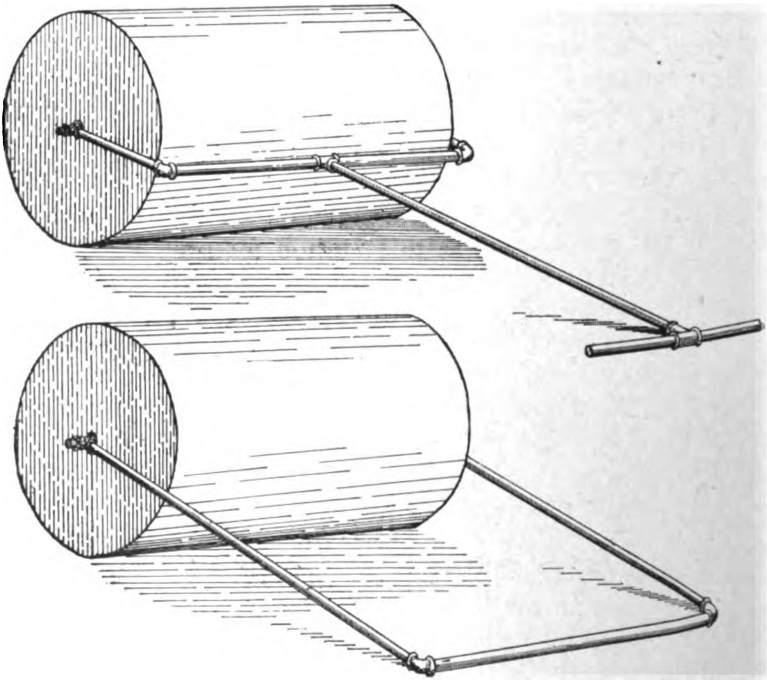
Green corn. Corn in the roasting-ear stage was cut from the cob and treated with a poisoned mixture prepared by dissolving an ounce of strychnia sulphate in a pint of hot water and mixing this with a pint of thick sugar syrup. This bait proved to be of little value, for in seventy-six per cent of the trials it was left untouched. In the remaining cases one-third of the runways continued to be worked.

Corn. Corn soaked over night and then treated with the poisoned syrup prepared at this Station for prairie dogs gave largely negative results. Seventy-five per cent of the runs treated continued to be worked by moles. Syrup prepared for pocket gophers was used on soaked corn as bait with somewhat better results, about fifty-six per cent of the runways treated showing no further evidence of mole operations.

CATCHING ALIVE. If one cares to take the time in morning or evening he can often catch a mole at work by watching in a spot where fresh burrowing operations have been noted. Approach very quietly the place where the earth is being heaved up and suddenly strike a spade into the ridge behind the animal and throw it out on the surface. If no spade or other suitable implement is at hand stamp the burrow down behind the mole with the foot and then subject the spot directly over the mole to like treatment or dig the animal out by hand.

When watering a lawn or irrigating a garden one can occasionally drive a mole to the surface by permitting a stream of water from hose or ditch to run into an open burrow for some time. This plan is not usually practicable, however, for it entails a waste of water, softens up spots in the lawn until they become boggy, and may result in flooding a cellar through an unsuspected runway following along the wall.

ROLLING THE LAWN. Repeated leveling of the mole ridges on a lawn by means of a suitable roller not only tends to discourage the animals from making any further inroads on the premises, but prevents that injury to the grass roots which would otherwise have resulted, and makes the lawn always appear sightly. A practical and substantial roller for this purpose may be made of cement, with gas-pipe axle and handles. It should weigh about 200 pounds.



Types of lawn rollers made of cement, with gas-pipe axle and frame. The form for setting the cement may be of wood, very narrow slats, or of galvanized iron. In the latter case the form may be left on the roller. The dimensions of the roller should be about 20 inches long by 14 inches in diameter.

TREATING SEED CORN TO PROTECT IT FROM BURROWING ANIMALS.

For several seasons the Station has been working on a line of experiments to determine means for preventing the theft of seed corn in the ground. A preliminary circular or bulletin on the subject was published a year ago, but at that time sufficient progress had not been made to warrant any final recommendations. Since the mole is very generally charged with these thefts, and since he is in reality accessory to the crime—by constructing highways which the real thieves follow—the results of this seed corn treating can be very properly given here.

These experiments have all followed one of three lines—baiting the pests some days in advance of planting, regular planting of poisoned seed, and surface coating of seed with ill-flavored substances.

POISONED BAIT. By baiting is meant the introduction of poisoned grain baits into the mole runways through small openings made with a stick. This puts the bait where it is sure to be found and minimizes the danger of its being taken by birds or any other animals than those for which it was intended. This plan also tends toward conserving the mole and destroying the mice, for the former is exceedingly suspicious of poisoned baits, while the latter will accept them readily. The sharp stick used for making the openings through the roof into the burrow should be no larger than one's finger. Close this opening with a clod after dropping in the kernels of poisoned grain. Corn, wheat or Kafir treated with the poisoned syrup prepared at the Station for destroying pocket gophers will make efficient baits. An excellent syrup for poisoning these grains may also be made as follows: Dissolve one ounce of strychnia sulphate in a pint of hot soft water. Add to this a pint of thick sugar syrup and mix the two by stirring. Pour enough of this syrup over the grain to thoroughly coat it. The one-quart mixture prepared as above should be sufficient for a half bushel of grain.

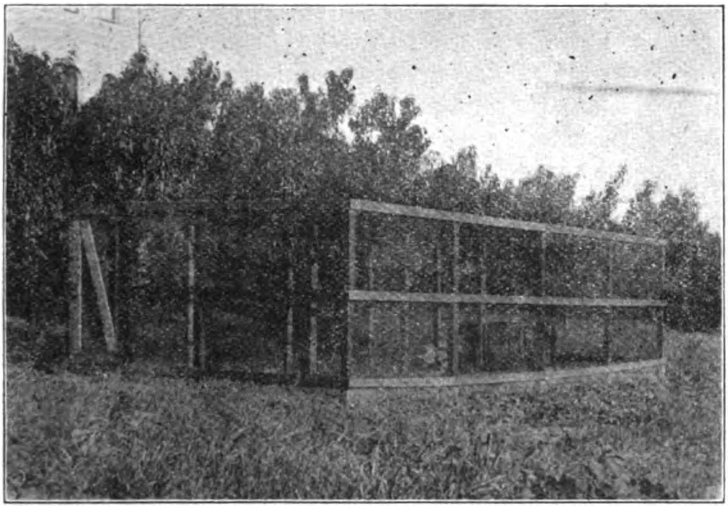
POISONED SEED. An exhaustive series of tests has proven that seed corn intended for the regular planting may be poisoned without any resulting injury to its germinating qualities. For this poisoning, strychnia sulphate should be used.

As will be seen by reference to the table on page 35, both arsenic and corrosive sublimate seriously affect the viability of the seed. If the corn can be planted by hand it may be treated with either of the poisoned syrups referred to above. In garden plantings or along creek bends where the mole-mice pest is the most serious this method of planting can be followed to advantage. The seed corn may be allowed to dry after treating with the syrup, but if planted at once it should be handled with a spoon.

To poison seed corn so that it will still work in a planter, dissolve one ounce of strychnia sulphate in eight quarts of hot water, preferably rain water. In this solution, after cooling, soak one peck of seed for forty-eight hours, using as a container a vessel that will close tightly enough to prevent evaporation. When draining the corn at the end of the period of soaking save the poisoned water, as there will ordinarily be enough to soak a half peck more of seed. When corn so treated is thoroughly dried it will return to its former bulk, will have its germinating qualities unimpaired, and will work in a planter as well as untreated seed. Field experiments seem to indicate, however, that if heavy rains follow shortly after planting the poison tends to leach out of the grain. Under similar conditions the surface coating given by the poisoned syrup will also be partially washed off.

COATING SEED WITH OFFENSIVE SUBSTANCES. During the past two seasons an extensive series of tests has been made in treating seed corn with various ill-tasting substances calculated to deter burrowing animals from taking it. The results in most cases have been negative; that is, the seed was usually taken about as readily as though it had not been treated at all. In every case a counted number of kernels of treated corn were put out in not less than twenty different locations and the trial repeated at different seasons. All locations were accurately marked and carefully examined at regular intervals. The notes show that none of the substances used prevented the kernels of corn, or a portion of them, from being eaten or carried off. In most cases the corn was introduced directly into surface runways through an opening made by a lead pencil or small stick. Field plantings of treated corn were also made for two seasons on lands adjacent to small creeks. One of these plantings was entirely taken by fox squirrels as soon as the young plants began to show aboveground. A second planting was protected from a like fate by the use of traps and shotgun, and a fairly good stand of corn secured.

Experiments with about a dozen live spermophiles (striped ground squirrels) kept for months in the field cage shown in the illustration on this page demonstrated that these little animals will eat some of the corn, no matter how it has been previously treated. That, too, in spite of the fact that they were given untreated corn to eat during the progress of the experiments. When the freshly treated corn was exposed in saucers or trays they would generally eat the more palatable kinds first. When planted in plots and allowed to germinate or to grow to the height of an inch or two they would dig up all kinds indiscriminately.



The field cage for conducting experiments with captive mammals at the Kansas State Experiment Station.

The results of the tests of deterrent substances may be here briefly summarized:

SUBSTANCES WHICH HAVE BEEN FOUND TO INJURE THE GERM OF THE SEED. Kerosene, crude petroleum, copperas, crude carbolic acid, fish oil, spirits of camphor and turpentine, when used in sufficient quantity or strength to impart an odor to the corn, seriously injured the germinating powers of the grain. To treat the seed with any of these substances in such small quantity or dilute form as not to injure the germ is a waste of time, for the slight taste or odor imparted is soon dissipated by contact with the soil. Corn soaked in kerosene—an oft recommended treatment—for as short a time as five minutes, seriously impaired its germinating qualities.

SUBSTANCES NOT INJURIOUS TO THE SEED, BUT OF NO VALUE OR NOT AVAILABLE. Mixing pulverized gum camphor with the dry grain and storing in a closed vessel for some days has been recommended as an efficient treatment. The results were entirely negative. Little or no odor was imparted to the grain, and when the latter was placed in mole runways it was readily taken. Coating the corn with a thin paste of red lead and water has been recommended for protecting it against crows. When seed thus treated was placed in the spermophile cage, along with six other trays of corn that had been coated with deterrents, that subjected to the red lead treatment was the first to be eaten. Pine tar was used in some of the experiments. It has a strong odor but leaves the grain too sticky to work in a planter.

SUBSTANCES WHICH MAY BE USED WITH SOME DEGREE OF SUCCESS. Coal tar makes an ideal coating of a rich brown color and a persistent gassy smell. It dries nicely, is not in the least sticky when dried, and will therefore work well in a planter. Wet the grain with a little warm water before stirring in the tar. A tablespoonful of the latter will be sufficient for a peck of corn. The mass must be thoroughly mixed and then dried before attempting to plant. Mice show some aversion to corn thus treated, but ground squirrels do not seem to object to the coating. This deterrent is generally regarded as effective against crows, particularly by Eastern farmers. The Station has had no opportunity to test the matter. Soaking corn in strong tobacco decoction for twenty-four to forty-eight hours gives good results in some cases. Of course the grain must afterwards be thoroughly dried if it is to be planted by machine. It will still have a strong odor and will not be sticky. The decoction was prepared by steeping a pound of ordinary smoking tobacco in eight quarts of water. This will serve for soaking a peck of corn.

Treatment of Seed Corn with Deterrents and Poisons.
Germination Table.

(Average germination of the ten varieties of check or untreated corn in this test about 95 per cent.)

Substance used.	Treatment.	No. of grains tested.	Germination.
Kerosene	Corn surface-coated just before planting	600	74%
Coal tar	1 tablespoonful to peck. Planted at once	500	92
Coal tar	1 tablespoonful to peck. Dried before planting	1,100	95
Zenoleum	Corn surface-coated just before planting	400	93
Zenoleum	Corn surface-coated and dried before planting	1,000	93
Crow repellent	Corn surface-coated just before planting	200	94
Crow repellent	Corn surface-coated and dried before planting	800	94
Red lead	Corn surface-coated with paste in water	500	96
Tobacco	Decoction—1⅔ oz. to 1 qt. water. Soak 36 hrs.; dry	900	93
Gopher poison	Corn surface-coated just before planting	500	92
Gopher poison	Corn surface-coated and dried before planting	1,000	96
Strychnia sulphate	⅛ oz. to 1 qt. hot water; corn soaked 48 hrs.; dried	1,000	93
Water	Corn soaked 48 hrs.; dried before planting	1,000	93
Arsenic	Corn wet in very dilute mucilage; powdered with arsenic	100	82
Corrosive sublimate	Corn soaked in 1% solution for 1 hr.; dried	50	14
Spirits of camphor	Corn soaked in spirits for 24 hrs.; dried	100	00
Pine tar	Corn surface-coated; dried before planting	100	92
Crude petroleum	Corn surface-coated just before planting	100	18
Fish oil	Corn surface-coated just before planting	100	54
Crude carbolic acid	Corn surface-coated just before planting	100	44
Copperas	1 oz. to one gallon of water; corn soaked 24 hrs.; dried	100	79

MOLES FOLLOWING THE LISTER FURROW. In connection with the report on treating seed corn it may be well to give here the results of some observations on the mole's alleged habit of following in the bottom of the listed furrow. There is no doubt but that the little animal is guilty, as charged, of following a course by preference along the straight trail of freshly loosened earth made by the drill-shoe. That he is seeking out the seed corn is only a matter of inference from his following the furrow. The truth of the matter is that it is probably the white grub that attracts him, not the corn. The presence of moles in rich lawns, garden plots and along creeks in cornfields is a symptom, not a disease. The white grub is the disease. The record of accurate observations on a twenty-acre cornfield in Illinois shows an average of over thirty-four grubs to the square yard. It is needless to say that this field produced but little corn. The grub eats the young corn shoots before they are up and attacks the root system at any time throughout the season.

The following table gives the results of careful measurements and counts made day by day on twenty rows of corn in rich ground along a little creek. The data given are calculated to show to what extent the mole traverses or crosses the lister furrow:

PLANTING "A."					PLANTING "B."				
Row.	Greatest number of places traversed by runs at one time....	Greatest total length of runs in furrow at any one time........	Greatest number of times run merely crossed the furrow..	Total length of row....	Row.	Greatest number of places traversed by runs at one time....	Greatest total length of runs in furrow at any one time........	Greatest number of times run merely crossed the furrow..	Total length of row....
		feet.		*feet.*			*feet.*		*feet.*
1........	9	159	3	825	1........	6	170	8	825
2........	11	59	8	825	2........	11	93	5	825
3........	10	75	10	825	3........	13	459	4	825
4........	8	41	6	825	4........	14	246	4	825
5........	10	34	8	756	5........	11	107	3	756
6........	4	19	13	756	6........	9	157	2	756
7........	5	62	6	696	7........	6	56	3	696
8........	4	20	9	354	8........	5	69	4	354
9........	3	29	6	354	9........	7	178	2	354
10........	3	38	4	354	10........	6	70	5	354

The above figures give the greatest totals noted at any one time. After heavy rains counts and measurements would differ from these figures. Probably nearly the entire lengths of the rows were traversed at different times. The injurious effect of the mole's running under the young corn shoots was most noticeable in the dry periods. However, the number of shoots of corn known to have died from having their roots heaved up totaled but 53.

THE FOLLOWING BULLETINS

ARE AVAILABLE FOR DISTRIBUTION.

No. 12....Preliminary Experiments with Fungicides for Stinking Smut of Wheat.
No. 15....Additional Experiments and Observations on Oat Smut.
No. 52....Kansas Weeds—Preliminary Circular on Distribution.
No. 120....Tests of Forest Trees.
No. 121....Treatment and Utilization of Flood-damaged Lands.
No. 129....Kansas Mammals in their Relation to Agriculture.
No. 136....Press Bulletins Nos. 125-151.
No. 137....Variations in the Test of Separator Cream.
No. 138....Effect of Bacteria in Wash-water of Butter.
No. 139....The Study of Corn.
No. 140....Milking Machines.
No. 141....Commercial Seeds of Brome-grass and of English and Kentucky Blue-grasses: Adulterants and Substitutes and their Detection.
No. 143....Disposal of Dairy and Farm Sewage, and Water Supply.
No. 148....Law Regulating the Sale of Commercial Fertilizers.
No. 149....Prevention of Sorghum and Kafir-corn Smut.
No. 150....The Hen's Place on the Farm.
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No. 164....The Selection and Feeding of Laying Hens.
No. 165....Report of State Forester.
No. 167....A Quantitative Method for the Determination of Hardness in Wheat.
Circular No. 1....Treating Seed-corn to Protect it from Burrowing Animals.
Circular No. 2....Preparing Land for Winter Wheat.
Circular No. 3....Improved Seed Wheat.
Circular No. 4....Prairie-dog Situation.
Circular No. 5....Chinch Bug.
Circular No. 6....Variety Tests.
Circular No. 7....Corn Ear-worm.
Circular No. 8....Investigation of the Vitality of Kansas Seed-corn.
Circular No. 9....Rabies—Hydrophobia.
Circular No. 10....Provisions of the State Forest Law.

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Kansas State Agricultural College.

EXPERIMENT STATION.—Bulletin 169.

ED. H. WEBSTER, *Director.*

FARM BULLETIN.

Department of Chemistry.

J. T. WILLARD, *Chemist in Charge.*

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Fertilizers and Their Use.

BY

J. T. WILLARD, *Chemist.*
C. O. SWANSON, *Assistant Chemist.*
R. C. WILEY, *Assistant Chemist.*

MANHATTAN, KAN.
SEPTEMBER 19, 1910.
3166

Department of Chemistry.

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H. C. McLEAN	Assistant in Soil Analysis.

Work of the Department of Chemistry.

A large part of the work of the Department of Chemistry in the Experiment Station is in coöperation with other departments, by contributing the chemist's point of view in planning experiments, and in making the chemical analyses incident to investigations. Among these investigations are: Feeding experiments, conducted by the Department of Dairy Husbandry; experiments touching soil fertility, in charge of the Department of Agronomy; experiments in the study and improvement of wheat and alfalfa, by the Departments of Agronomy and of Botany, and experiments bearing upon the methods of handling and storing wheat, conducted by the Department of Milling Industry.

Among the lines of work more completely in charge of the Department of Chemistry are certain experiments touching the composition, digestibility and nutritive value of feeds; milling tests of wheat, and baking tests of flour; the collection and analysis of samples of soils, typical of the various regions of the state; the inspection and analysis of fertilizers sold in the state and the inspection and analysis of feeding stuffs sold in the state.

Bulletins are issued from time to time as required, or as the results of investigations warrant. These may be obtained without charge by addressing the Director of the Experiment Station, Manhattan, Kan.

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Fertilizers and Their Use.

BY

J. T. **Willard**, *Chemist.*
C. O. **Swanson**, *Assistant Chemist.*
R. C. **Wiley**, *Assistant Chemist.*

The use of commercial fertilizers in Kansas has not yet attained any extended volume. Under the provisions of an act of the legislature passed in 1907, and printed in full in bulletin No. 148, the Experiment Station is charged with certain duties in connection with the sale of fertilizers. It is unlawful within the state of Kansas to sell, offer for sale or possess for sale any commercial fertilizer which has not been officially registered by the Director of the Experiment Station of the Kansas State Agricultural College, and previous to registration the manufacturer or seller of any brand of commercial fertilizer is required to submit a statement of its guaranteed composition. If this is satisfactory to the said Director, he registers the fertilizer upon the payment of a registration fee of twenty-five dollars by the manufacturer or seller. This payment is once for all, and the law forbids changing the guaranteed composition of any brand of fertilizer after it is registered. This is to protect consumers in the use of a given brand which, if changes were permitted, might be found quite unsatisfactory at later dates. Hence, if a manufacturer desires to make a change in his fertilizer he must give it a new brand and register it under the new name.

The law also provides that the Experiment Station chemist and his deputies shall make inspection of fertilizers sold or offered for sale in the state of Kansas, and shall procure samples of the different brands registered for sale in the state, that they may be analyzed for comparison with the guaranty of the manufacturer. These samples are obtained from lots actually on sale and are not specially prepared and furnished by the manufacturer.

TABLE I. Composition of inspection samples of fertilizers compared with the guaranties of manufacturers.

	BRAND OF FERTILIZER.	Manufacturer.	Minimum percentage of total nitrogen.		Minimum percentage of phosphorus in phosphates.								Minimum percentage of potassium in compounds soluble in water.		Maximum percentage of chlorine in compounds soluble in water.	
					Soluble in water.		Reverted.		Insoluble.		Total.					
			Found....	Guaranteed....	Found....	Guaranteed....	Found....	Guaranteed....	Found....	Guaranteed....	Found....	Guaranteed....	Found....	Guaranteed....	Found....	Guaranteed....
1	Lawn & Garden	Armour Packing Co	2.79	2.88	......	......	......	......	0.39	......	4.55	3.49	3.08	3.32	......	......
2	Special Grain	Swift & Co.	1.26	1.65	2.71	2.49	......	......	.16	0.88	4.47	5.25	1.44	1.66	0.60	1.51
3	Helmet Brand 2-8-2	Armour Packing Co	1.57	1.64	......	......	......	......	.16	......	4.62	3.49	1.56	1.66	......	1.65
4	Fine Ground Beef Bone	Armour Packing Co	2.92	2.46	......	......	......	......	7.56	7.85	11.22	10.47	......	......	......	......
5	Onion, Potato & Tobacco	Swift & Co.	1.61	1.65	1.95	2.18	......	......	1.10	1.31	4.49	4.80	5.16	5.82	.90	......
6	Pure Bone Meal	Swift & Co.	2.79	2.50	......	......	......	......	6.57	6.00	11.49	10.92	......	......	......	......
7	Enterprise Brand	Hull & Dillon Co.	6.81	6.74	......	......	......	......	1.59	1.07	4.37	4.02	.24	.44	2.00	......
8	Raw Bone Meal	Armour Packing Co	4.02	3.70	......	......	......	......	7.52	8.29	10.31	10.47	......	......	......	......
9	Special Potato	Armour Packing Co	1.53	1.64	......	......	......	......	.35	......	4.88	3.49	8.84	8.30	6.50	......
10	Fine Ground Beef Bone	Armour Packing Co	3.33	2.46	......	......	......	......	7.51	7.85	11.09	10.47	......	......	......	......
11	Lawn & Garden	Armour Packing Co	2.72	2.88	......	......	......	......	.45	......	3.94	3.49	3.78	3.32	4.50	......
12	Special Potato	Armour Packing Co	2.72	1.64	......	......	3.81	3.49	.71	......	4.52	3.49	4.95	8.30	.13	......
14	Ammoniated Dissolved Bone & Potash	Armour Packing Co	1.67	1.64	......	......	4.45	4.36	.46	......	4.91	4.36	1.68	1.66	2.10	1.65
15	Lawn & Garden	Armour Packing Co	2.98	2.87	......	......	4.08	3.49	1.57	......	5.65	3.49	3.14	3.32	.30	......
16	Lawn & Garden	Armour Packing Co	2.86	2.87	......	......	4.25	3.49	.48	......	4.68	3.49	3.14	3.32	.28	......
18	Special Potato	Armour Packing Co	1 76	1.64	......	......	4.87	3.49	.19	......	5.06	3.49	7.52	8.30	.48	......
19	Lawn & Garden	Armour Packing Co	2.60	2.87	......	......	4.75	3.49	.41	......	5.16	3.49	3.24	3.32	.33	......
20	Fine Ground Beef Bone	Armour Packing Co	2.70	2.46	......	......	5.38	2.61	5.18	7.85	10.56	10.48	......	......	......	......
21	Raw Bone Meal	Armour Packing Co	3.95	3.07	......	......	4.31	2.18	6.15	8.29	10.46	10.47	......	......	......	......
22	Helmet Brand 2-8-2	Armour Packing Co	1.63	1.64	......	......	4.54	3.49	.19	......	4.78	3.49	1.84	1.66	2.20	1.65
23	Helmet Brand 2-8-2	Armour Packing Co	1.95	1.64	......	......	3.86	3.49	.45	......	4.31	3.49	1.68	1.66	2.00	1.65
24	Lawn & Garden	Armour Packing Co	2.88	2.87	......	......	4.29	3.49	.45	......	4.74	3.49	3.13	3.32	.30	......
25	Helmet Brand 2-8-2	Armour Packing Co	1.61	1.64	......	......	3.69	3.49	.78	......	4.47	3.49	1.52	1.66	1.90	1.65
23	Ammoniated Dissolved Bone & Potash	Armour Packing Co	1.63	1.64	......	......	4.67	4.36	.88	......	5.55	4.36	1.45	1.66	1.85	1.65
28	Superphosphate	Swift & Co	1.54	1.65	......	......	3.76	3.49	1.46	1.75	5.22	5.24	1.45	5.24	1.70	1.66
29	Pure Raw Bone Meal	Swift & Co.	4.00	3.75	......	......	......	......	......	......	......	10 04	......	......	......	......
30	Pure Special Bone Meal	Swift & Co.	1.52	......	......	......	......	......	......	......	12.09	......	......	......	......	......
31	Special Grain	Swift & Co.	1.99	1.65	2.85	3.49	4.72	4.87	.87	.88	5.09	5 25	1.55	1.66	1.70	1.51
32	Pure Bone Meal	Swift & Co.	2.15	2.50	......	......	7.08	4.92	4.02	6.00	11.10	10.04	......	......	......	......
33	Vegetable Grower	Swift & Co.	4.50	3.29	.76	2.36	4.29	3.93	1.61	.87	5.90	4.80	8.58	8.31	1.20	......

34	Pure Bone Meal	Swift & Co.	3.49	2.50	......	......	8.01	4.92	4.50	6.00	12.51	10.92	......	......	......	......
35	Special Grain	Swift & Co.	2.52	1.65	1.24	3.49	3.69	4.87	1.98	.88	5.62	5.25	1.98	1.66	2.10	1.51
36	Special Potato	Armour Packing Co.	2.38	1.64	......	......	3.51	3.49	.49	......	4.00	3.49	8.08	8.30	1.10	......
37	Ammoniated Dissolved Bone & Potash	Armour Packing Co.	1.84	1.64	......	......	4.87	4.36	.18	......	5.00	4.36	1.95	1.66	2.00	1.65
38	Lawn & Garden	Armour Packing Co.	3.82	2.87	......	......	4.14	3.49	.11	......	4.25	3.49	3.12	8.32	2.10	......
39	Fine Ground Beef Bone	Armour Packing Co.	3.25	2.47	......	......	6.18	2.62	4.17	7.87	10.35	10.48	......	......	......	......
40	Vegetable Grower	Swift & Co.	3.30	3.29	2.12	2.36	4.53	1.57	.54	.87	5.07	4.80	9.52	8.31	.30	......
41	Fine Ground Beef Bone	Armour Packing Co.	2.48	2.47	......	......	4.39	2.62	6.35	7.86	10.74	10.48	......	......	......	......
42	Helmet Brand, 2-8-2	Armour Packing Co.	1.80	1.64	......	......	3.62	3.49	1.49	......	5.11	3.49	1.78	1.66	1.80	1.65
43	Pure Raw Bone Meal	Swift & Co.	4.25	3.75	......	......	......	......	......	......	9.75	10.04	......	......	......	......
44	Special Grain	Swift & Co.	2.19	1.65	3.59	3.49	4.84	4.37	.16	.88	5.00	5.25	1.81	1.66	1.50	1.51
45	Superphosphate	Swift & Co.	2.26	1.65	2.49	2.18	4.72	3.49	1.46	.87	6.18	4.37	1.85	1.66	1.50	1.51
46	Pure Bone Meal	Swift & Co.	2.12	2.50	......	......	4.73	4.92	5.50	6.00	10 23	10.92	......	......	......	......
47	Pure Special Bone Meal	Swift & Co.	1.35	......	......	......	......	......	......	......	10.40	......	......	......	......	......
48	Raw Bone Meal	Armour Packing Co.	4.55	3.70	......	.....	2.98	2.18	6.96	8.29	9.94	10.48	......	......	......	......
50	Kaw Grain Grower	American Reduction and Fertilizer Co.	2.18	1.65	1.30	2.00	3.70	3.50	.46	.85	4.16	4.35	2.65	1.66	.50	2.00
51	Kaw Special	American Reduction and Fertilizer Co.	1.55	2.00	1.57	1.50	3.41	.70	1.45	1.80	4.86	4.00	5.10	4.00	1.00	2.50
52	Kaw Special Potash Mixture	American Reduction and Fertilizer Co.	.87	.41	1.78	1.00	2.84	1.75	.30	.42	3.15	2.17	4.45	5.00	.70	2.50

The expense of inspection and analysis is met by means of the registration fees, and an inspection tax of twenty-five cents per ton collected by means of tags which are to be attached to the packages of fertilizer or delivered with bulk lots. These tags must be obtained from the Director of the Experiment Station.

The law went into effect September 30, 1907, and this bulletin in the accompanying tables gives the results of analyses of the samples of fertilizers taken up to June 30, 1909. Comparatively few brands of fertilizers have been registered, and in some cases these have not been found in the market, although the entire state has been fairly well covered in the inspection. In some cases small quantities of fertilizers had been in stock, but none remained at the time of the inspector's visit. The observations of the inspectors would indicate that comparatively small amounts of commercial fertilizers are sold in this state.

The results of the analyses of the inspection samples of fertilizers collected show that usually the amount found is up to that guaranteed, or at least within the limit of one-fifteenth deficiency tolerated by law. In a few instances, however, there is a considerable deficiency, indicating a possible blunder in compounding the particular lot of fertilizer sampled. Comparatively few brands of fertilizers are registered in this state, and their manufacturers are evidently disposed, on the whole, to maintain the quality of their goods as placed upon the market.

TERMS RELATING TO FERTILIZERS.

Some explanation of the terms used in connection with fertilizers seems advisable at this point, especially as the science of chemistry and its specific terms cannot be assumed to be understood by the average farmer and yet are indispensable in discussing or comparing fertilizers and soils, as well as many other classes of substances with which agriculture is concerned.

When one consults the bulletins upon soils or fertilizers issued by most experiment stations he finds the expressions "potash," "phosphoric acid," "nitrogen," "lime," "ammonia" and others in common use. In the tables presented in this bulletin, while these terms may be employed at times in stating the composition of fertilizers, the significant constituents will be expressed as quantities or percentages of some chemical element. That the reader may understand the relation between this mode of expression and the older one which is in more general use, and may have a basis for understanding the limitation and value of each as a mode of indicating the usefulness of a fertilizer, an attempt will be made in the following paragraphs to present the matter in an elementary way in the hope that even those who have had no opportunity to study chemistry may grasp the essential ideas.

When the chemist investigates the various substances of which the air, earth, rocks, water, plants, animals, etc., consist, he finds that most of these are compound in character; that is, by suitable chemical treatment he can decompose them into other substances. If this process of decomposition be continued to a sufficient extent he finally may obtain substances which are incapable of further decomposition by him. These simple, undecomposable substances are the chemical elements. Many of these are well known, such as iron, copper, gold, silver, lead, tin, zinc and sulphur. Oxygen and nitrogen are elements which make up nearly the entire bulk of the air. Hydrogen is an element of which water contains 11 per cent, the remainder being oxygen.

Phosphorus is an element that is not frequently seen in common life and does not occur as such naturally. It is, however, readily prepared by the chemist. Carbon is the element which is most typical of the substances of which plants and animals consist, and when these are strongly heated without free access of air a residue of carbon with small amounts of mineral substances is left as a soft black substance known as charcoal. The hydrogen and nitrogen, and a portion of the carbon and other elements, will have been expelled in the form of volatile substances. The element carbon not only occurs in the form of charcoal but also in the diamond, and in graphite, the material used in the preparation of lead pencils.

Sodium, potassium and calcium are important metals, which are, however, never found in the uncombined state naturally, but can be separated from the compounds in which they occur by suitable chemical processes. Chlorine is a gas which also is found in nature only in combination. It is one of the constituents of common salt, the metal sodium being the other constituent.

It will be seen that most of the substances named above as elements do not occur as such in nature. As we study chemistry we find that there is a considerable tendency for elements to combine in pairs; for example, common salt consists of sodium and chlorine, water of hydrogen and oxygen, lime of calcium and oxygen, sulphur trioxide of sulphur and oxygen, phosphorus pentoxide of phosphorus and oxygen. In fact, there is a large class of compounds known as oxides each member of which consists of oxygen combined with another element. Furthermore, it has been found that many compounds are of such composition that they may be regarded as formed by the union of two oxides; thus water, a compound of oxygen and hydrogen, will combine with sulphur trioxide, a compound of oxygen and sulphur, to form sulphuric acid, which therefore contains hydrogen, sulphur and oxygen. Chemists have adopted certain symbols to represent in some sense the chemical elements. These symbols suggest not only the name of the element but they have a quantitative meaning—that is, they indicate the relative weights of the substances in a compound. The symbol H, for example, indicates hydrogen; O, oxygen; S, sulphur; P, phosphorus, but the relative weights implied by these symbols are 1, 16, 12, 32 and 31, respectively. It has been found that if certain relative weights are thus assumed to be represented by the symbols of the elements comparatively simple expressions known as formulas can be used to designate their composition. This may be illustrated to a certain extent with the hope of giving the reader some idea concerning the meaning of chemical formulas without expecting him to completely understand the reasons for them. The relative weights assumed to be signified by these chemical symbols are known in chemistry as the atomic weights, and are believed to have a fundamental connection with the actual structure of matter. It has been found, however, that chemical compounds cannot all be accounted for by assuming that, in the combination of elements to form compounds, the quantities entering into the combination are always in the same relation as the so-called atomic weights. It is, however, always possible to represent the compound by assuming that the elements enter into it in relatively simple multiples of the atomic weights. These ideas may be illustrated by means of a few examples. The combining weights, or atomic weights, of all of the elements with which we shall be concerned in this bulletin are, in round numbers:

Hydrogen, H, 1.	Potassium, K, 39.	Sulphur, S, 32.
Oxygen, O, 16.	Calcium, Ca, 40.	Phosphorus, P, 31.
Nitrogen, N, 14.	Magnesium, Mg, 24.	Chlorine, Cl, 35.5.
Sodium, Na, 23.	Carbon, C, 12.	

In using these symbols and atomic weights to indicate substances produced by the combination of these elements we write the symbols of the elements entering into the compound side by side, and if more than one atomic weight of any element is to be represented a small figure is placed to the right and somewhat below the symbol. There is, for example, a compound of potassium and chlorine known as potassium chloride. If this compound be carefully analyzed it is found to contain the metal potassium and the nonmetal chlorine in the ratio of 39 to 35.5. We may therefore adopt the formula KCl as representing potassium chloride, not only as showing the chemical elements of which it consists but also their relative amounts, since "K" is always to be understood as representing a relative quantity of 39 and "Cl" one of 35.5. The metal calcium also forms a compound with the nonmetal chlorine. Chemical analysis shows that in this the relative amounts of calcium and chlorine are 40 and 71; that is, we have with one combining or atomic weight of calcium two atomic weights, 2 x 35.5, of chlorine. We can represent this compound both as to the kinds of elements of which it consists and their relative amounts by the formula $CaCl_2$, in which Ca indicates a relative weight of 40 and Cl a relative weight of 35.5, and the $_2$ shows that this last is taken twice. This mode of indicating the quantitative composition of compounds may seem at first to be roundabout and cumbrous. It is, however, in the direction of simplicity, as relatively simple formulas indicate compounds the composition of which could not be represented simply by percentages. And, moreover, by this system very simple relations are found to exist among the different classes of compounds. Thus it will be seen that there is a simple relation between potassium chloride, KCl, and calcium chloride, $CaCl_2$. In the latter there are two combining weights of chlorine for one combining weight of the calcium, while in the former there is one combining weight of the chlorine for one of the potassium. If we should express these compounds in percentages we would have in the potassium chloride 52.3 per cent of potassium and 47.7 per cent of chlorine, and in the calcium chloride 36 per cent of calcium and 64 per cent of chlorine, figures which do not give any hint of the simple relation existing between the two compounds in respect to the amount of chlorine. Throughout the whole realm of chemistry the representation of chemical compounds and their relations among each other is brought out only when the symbols of the elements are at the same time taken to indicate a definite quantitative composition represented by the atomic weights taken one or more times as the formula may indicate.

As indicated above, it was early noticed that elements tended to combine in pairs and that the compounds so produced might combine with other compounds. We may illustrate this further. Calcium and oxygen combine in the ratio of 40 of calcium to 16 of oxygen to form the common compound lime—that is, quicklime. As the numbers in this ratio are the same as those given above for the combining weights the formula of the compound is CaO. This formula represents that calcium and oxygen are combined in the ratio of 40 to 16 by weight just as definitely as if the fact were stated. Sulphur and oxygen form the compound sulphur trioxide, the relative amounts of sulphur and oxygen being 32 and 48, respectively. The combining weight of sulphur being 32, and of oxygen 16, one-third of 48, we must represent sulphur trioxide by the formula SO_3. Lime and sulphur trioxide will combine together to form the compound calcium sulphate. In this the relative amounts of calcium, sulphur and oxygen are 40, 32 and 64, respectively, and hence it may be represented by the formula $CaSO_4$. This formula it will be seen is equal to CaO and SO_3 added together. In an earlier stage of chemical science this was written CaO,SO_3. This emphasized the idea held at that time that chemical compounds in general are formed by the union of two things. In this case the two were CaO, lime, and SO_3, sulphur trioxide, or, as it was then called, sulphuric acid.

Let us take another example. Phosphorus and oxygen combine to form phosphorus pentoxide. In this the ratio of phosphorus to oxygen is as 62 is to 80. As the atomic weights of phosphorus and oxygen are 31 and 16, respectively, the formula of phosphorus pentoxide is found by dividing 62 by 31, and 80 by 16, and is thus P_2O_5. This substance in the early part of the last century was called phosphoric acid. Calcium oxide, or lime, and phosphorus pentoxide, or "phosphoric acid," are capable of uniting together to form the compound calcium phosphate, in which the relative amounts of calcium, phosphorus and oxygen are 120, 62, and 128, respectively. If these numbers be divided by the atomic weights of those elements we obtain, as the formula for calcium phosphate, $Ca_3P_2O_8$. It will be seen that in composition this is equivalent to three of calcium oxide plus one of phosphorus pentoxide, and this relation may be brought out by writing the formula $3CaO,P_2O_5$; that is, the compound may be said to consist of "lime" and "phosphoric acid," to use the old terms, or calcium oxide and phosphorus pentoxide, if the modern names be used. Without going into details, it may be stated that by this old system potassium phosphate would be represented as $3K_2O,P_2O_5$. The name "potash" was given to the potassium oxide, K_2O, but unfortunately the term is also applied to other compounds. Common saltpeter contains potassium, nitrogen and oxygen, and the relative amounts of these elements are 39, 14 and 48, respectively, numbers corresponding to the atomic weights, excepting that in the case of oxygen it is three times as great. We therefore give the substance the formula KNO_3. If this be multiplied by 2, making $K_2N_2O_6$, it will be seen to be equivalent to K_2O,N_2O_5. In the early days previously referred to, N_2O_5 was known as nitric acid, and this substance was said to consist of "potash" and "nitric acid." In a similar way Chili saltpeter, now represented by the formula $NaNO_3$, was given the formula Na_2O,N_2O_5, and calcium nitrate, the old name for which was nitrate of lime, now given the formula CaN_2O_6, or $Ca(NO_3)_2$, was represented as CaO,N_2O_5.

By studying the old formulas as given above it will be seen that each of them is twofold in its nature and represents an oxide of a metal and an oxide of a nonmetal, and that these oxides occur in the different substances; thus CaO, "lime," is represented as present in the calcium sulphate and calcium phosphate and calcium nitrate; the "phosphoric acid," P_2O_5, was represented as present in potassium phosphate as well as calcium phosphate and others; "potash," K_2O, was in potassium phosphate, potassium nitrate, etc.; nitric acid, N_2O_5, is present in calcium nitrate, potassium nitrate and sodium nitrate. It will be seen that this binary system possesses some obvious advantages and that it is possible to speak of a series of substances as containing "lime," another series as containing "phosphoric acid," another "potash," another "sulphuric acid," etc. This system of thought and method of stating results was used so much in connection with the analysis of soils, rocks and fertilizers during the last century that a large mass of material was accumulated in which the results of the analyses are expressed in these old terms.

However, with the progress of chemical science the views concerning the nature of chemical compounds have changed radically, and many of the names used above are no longer used in that sense in the systematic science of chemistry. The young student of to-day studies an entirely different substance than P_2O_5 under the name of "phosphoric acid"; "sulphuric acid" in modern language is not SO_3; "nitric acid" is not N_2O_5; "potash" is not K_2O; and hence the students of chemistry in our high schools and colleges to-day require special instruction in order to enable them to understand the antiquated expressions used in describing the composition of soils and fertilizers. It seemed to those concerned in drafting the fertilizer law for the state of Kansas that the only proper thing was to apply to fertilizers the system of naming used throughout the science of chemistry in almost every relation; that it should be placed abreast of the times and not start with a system of naming that has long been out of date and presents many complications and inconsistencies not yet brought out here. Hence the law specifies that the composition of fertilizers shall be stated in terms of the elements; that is, the amounts of potassium, phosphorus, nitrogen, etc., are to be stated rather than "potash," "phosphoric acid," or "ammonia." The problem is a difficult one to argue in a way intelligible to one who has not studied chemistry, but some of the embarrassments of the old system will be presented in as simple a manner as possible.

In the examples given above it is obviously possible to express the percentage of "potash", K_2O, "lime", CaO, "phosphoric acid", P_2O_5, etc., because in a sense each of those substances may be said to be present in the examples cited. There are, however, compounds used in fertilizers in which this is impossible. One of the important substances containing potassium used in fertilizers is potassium chloride, which contains potassium and chlorine only, and has the formula KCl. It is obvious that in no way can this be represented as containing K_2O, since it is free from oxygen. It cannot in any sense be said to contain "potash," K_2O, yet by the old system of stating the composition of fertilizers the analyst will report KCl as containing a certain percentage of "potash." What he really does in this case is to calculate from the results of his analysis the amount of "potash," K_2O, that would contain as much of the element potassium, K, as he finds in the fertilizer analyzed. The potassium found is equal in amount to that in the "potash" reported, and in a sense may be said to represent that amount of "potash." However, the oxygen is not there in that case, it is not the constituent which gives value to those potassium compounds which contain it, and it is far more logical to state the percentage of the particular elements in which we are interested than to calculate the amount of some other compound which may or may not be represented in the fertilizer and which is certainly not present as such any more than the potassium is present in the free and metallic state.

In the case of nitrogen, matters are in some states still worse, if possible. The nitrogen of fertilizers is present in various classes of compounds, among which are ammonium salts, nitrates, and the organic nitrogenous substances found in plants and animals. In stating the results of the analysis of a fertilizer it is the practice of some to ascertain the percentage of nitrogen and then to calculate the ammonia which if present would contain an amount of nitrogen equal to that found by the analysis. The fertilizer is then reported to contain that much "ammonia." In point of fact it not only does not contain ammonia, but in many cases it contains no compounds of ammonia, but instead nitrates and organic nitrogenous compounds. Reporting the results as "ammonia" is therefore wholly artificial, and is misleading in that the purchaser is given the wrong idea if he obtains any idea.

The question of the advisability of abandoning the old system of expressing the results of the analysis of fertilizers and soils, and substituting one in harmony with the later views that have dominated chemistry for over half a century, is one that has been discussed warmly at meetings of chemists, and thus far no unanimity of view has been attained. Those who are accustomed to the old system dislike to adjust themselves to a new one. They claim that it will be confusing to farmers. It may be conceded that farmers who have become accustomed to the old system may have difficulty in adapting themselves to a new one, but in point of fact comparatively few farmers understand the old system except that they have seen certain figures representing percentages set opposite the words "potash," "phosphoric acid" and "ammonia." The words mean nothing except as a means of identifying certain figures. If the results were reported in terms of the elements potassium, phosphorus and nitrogen the figures would be different and could not be compared directly with the results expressed by the old system. They would, however, be directly comparable with all results expressed by the modern system. It is, moreover, entirely practicable, as a transition plan, to have the composition of fertilizers expressed by both systems. This is, however, not necessary in this state, as the use of fertilizers is very limited and the intelligence of our citizens is such that they will be able to grasp promptly the relation between the antiquated system and the modern one, and will prefer the latter. As the use of fertilizers increases the education of the public concerning them will be in the same terms as those used in the education of children in the public schools and colleges, and the state will not be burdened by an excrescence in the form of a system of naming that has been out of use in scientific chemistry for half a century.

Some, in opposing the introduction of modern terms in connection with fertilizers, have argued that farmers might think that because the elements potassium and phosphorus are dangerously inflammable, and in that form would be wholly unfit to keep about a barn or apply to crops, fertilizers containing these elements should not be used. They lose sight altogether of the fact that potash and phosphoric acid, whether we use these names in the modern or the antiquated sense, represent compounds which it would be equally as dangerous to apply to crops and almost equally as unpleasant to handle, if not as dangerous. The fact of course is that the substances actually used as fertilizers are neither potassium, phosphorus, nitrogen, phosphoric acid, potash or ammonia, but quite different substances, in which, however, their value as a fertilizer is measured by the potassium, phosphorus or nitrogen which they contain. Were it possible to do so, the best mode of stating the composition of a fertilizer would be to give the percentage of each of the compounds actually present, such as potassium nitrate, potassium chloride, potassium sulphate, sodium nitrate, calcium phosphate, monocalcium phosphate, etc.

While the ideal mode of statement of the composition of a fertilizer is to state the amounts of each individual compound present, chemical analysis has not arrived at such a state of development as to enable us to analyze a fertilizer so as to tell exactly what compounds of the different elements are present. Thus, a fertilizer may contain potassium in potassium chloride, potassium sulphate, potassium carbonate, and other compounds, but it is quite impossible to so analyze it as to ascertain the amounts of potassium present in each of these classes. We can only determine the total amount of potassium, or the amount that is present in compounds soluble in water, or, possibly, in some other solvents.

The condition is similar in respect to nitrogen. The nitrogen of fertilizers now on the market may be present in the form of ammonium chloride, ammonium sulphate, potassium nitrate, sodium nitrate, calcium cyanamide, or in any one of a large number of nitrogenous organic compounds, some of animal and some of vegetable origin, and even in other compounds. It is at present far beyond the power of the chemist to analyze such a mixture and ascertain the exact proportion of each compound of nitrogen present. The best that can be done yields only partial results in this direction. Similar conditions apply to the compounds of phosphorus.

It will be seen, therefore, that it is impossible to report the composition of a fertilizer in terms that will state the amounts of each individual compound present, and the simplest method of reporting is to state the percentage of each significant element present. In the case of the nitrogenous substances, for example, while there are differences in the availability and agricultural value of them, since it is impossible to ascertain the amount of each compound, and the element nitrogen is the one found in all of them upon which the fertilizing value depends, a statement of the total amount of nitrogen would seem to be the simplest method of dealing with the question. In addition to this, however, it is possible with reference to some classes of compounds to investigate the matter somewhat more closely and learn something concerning the nature and amount of the individual compound or classes of compounds present. This is possible, and especially advantageous, in so far as we may determine the nitrogen, potassium, etc., present in compounds soluble in water and the amounts present in compounds insoluble in water. The soluble compounds are immediately available to plants, while the insoluble ones may require long and slow chemical processes to take place before plants can avail themselves of the needed elements. In addition to pure water other reagents are used in getting more detailed information concerning the character of the constituents of a fertilizer than is afforded by merely ascertaining the total amount of a given element present.

The value of potassium compounds not soluble in water is so slight that fertilizer laws uniformly take into account as valuable only those compounds which are soluble in water.

In the case of nitrogen the total amount of the element is usually ascertained, and when practicable the amount of this present as nitrates and ammonium salts, respectively, is also reported. The nitrogenous organic substances are so various in nature and of such diverse properties that as yet no mode of analysis has been agreed upon by which we may obtain a measure of the agricultural value of such nitrogenous substances. Some are no doubt practically equal to nitrates and ammonium salts, while others are so inert, so resistant to fermentation and other chemical change, that many of the states prohibit their introduction into fertilizers. Horns, hoofs, hair and feathers are examples of these inert substances. No analytical process has received general acceptance as affording a means of distinguishing accurately between the valuable organic nitrogenous substances and those that are worthless or nearly so.

In the analysis of fertilizers an attempt is made to ascertain the amount of phosphorus present in the different classes of phosphates, but this cannot be done with great exactness. fertilizer manufacturers are required to give a guaranty in respect to the phosphorus present in: (1) phosphates soluble in water, (2) reverted phosphates, (3) insoluble phosphates, and (4) the total phosphorus, which would be the sum of the other three. Reverted phosphates are soluble in a solution of ammonium citrate, and are sometimes referred to as "citrate-soluble phosphates." Ammonium citrate to a certain extent exerts a solvent power upon the reverted phosphate comparable with that exhibited by the roots of plants, and such phosphates are less valuable than those soluble in water. In considering the value of the phosphorus of a fertilizer, then, it is important to notice in what form of combination it is present.

MATERIALS USED IN FERTILIZERS.

Of the mineral elements required by plants only four are likely to be deficient in soils, namely, potassium, calcium, nitrogen and phosphorus, and the raw materials used in the manufacture of fertilizers are those which can be obtained on a commercial scale and contain one or more of these elements in a relatively high percentage. The commercial sources will not be treated at great length here, but on account of their general interest will be referred to briefly.

Potassium.

When plants are burned the residue left is known as the ash. If these plants are terrestrial the ash will contain a notable percentage of potassium; on the other hand, plants that have grown in the sea, though containing important amounts of potassium, also contain large amounts of the similar metal, sodium. For many years hardwood ashes were the chief source of potassium for fertilizers. The ashes of soft wood are much poorer in this element. No doubt the character of the forest growth of a region is determined largely by the quality of the soil, and hard woods grow only on soil rich in mineral substances, while the soft woods grow on poorer types. While hardwood ashes are still sought and applied, the chief supply of potassium compounds for fertilizers is a remarkable deposit of salts discovered in Germany about the middle of the last century. These deposits have been discovered in various parts of Germany, but the most important works are in the vicinity of Stassfurt, a small city about 100 miles southwest of Berlin. This wonderful deposit was discovered in a search for common rock salt, and the potassium compounds were at first regarded as of no value; but with the progress of agricultural chemistry they have become recognized as one of the most important of all the known resources of the world, and enormous amounts of potassium compounds are exported from Germany annually.

In the Stassfurt deposits the potassium is found in several different compounds. Among these are *sylvite*, KCl; *carnallite*, $KMgCl_3.6H_2O$; and *kainite*, $K_2SO_4.MgSO_4.MgCl_2.6H_2O$. Carnallite is the most important of these salts, but on account of its small percentage of potassium is not shipped in that form to distances remote from the mines. It is submitted to treatment whereby *potassium chloride* or *"muriate of potash"* in several grades of purity is obtained, and in this form is applied as a fertilizer. Kainite is used as a fertilizer, and is exported in large quantities. *Potassium sulphate*, or *"sulphate of potash,"* is manufactured from kainite and potassium chloride. This compound is not prepared in as large quantities as is potassium chloride, but for certain crops it is preferable. To a limited extent this compound occurs ready formed in the Stassfurt deposits.

Hardwood ashes are of little commercial consequence in this state, but when available should be recognized as valuable sources of fertility, especially of potassium. They contain, of course, the other ash constituents present in the original wood, excepting certain losses that take place in the combustion, and such as may have occurred by subsequent leaching, and hence contain valuable amounts of phosphorus. The nitrogen of the wood is mostly lost in the burning. In this connection it may be mentioned that coal ashes are of practically no chemical value, but may upon some soils be of use as improvers of the physical state.

For ordinary field crops the form of combination in which the potassium is employed does not matter much, the value depending upon the percentage of potassium present. It has been found, however, that with tobacco, potatoes and sugar beets the application of fertilizers containing chlorine is quite objectionable. Hence for these crops potassium sulphate should be used rather than potassium chloride (muriate of potash). Kainite, though containing its potassium as sulphate, carries large amounts of common salt (sodium chloride) as an impurity, and hence should not be used where chlorides are prejudicial.

Phosphorus.

Phosphorus is found in various classes of compounds, the most important of which as sources of fertilizers are: *Bones, rock phosphate, apatite,* and *basic slag* from certain iron furnaces. In bones and rock phosphate the phosphorus is present as a constituent of tricalcium phosphate, $Ca_3(PO_4)_2$. Apatite is closely related to this chemically, but contains fluorine and chlorine also. In basic slag a different combination is exhibited, known as tetracalcium phosphate, and to which the formula $Ca_4P_2O_9$ is ascribed.

The bones of animals directly or indirectly constitute an important source of phosphorus. *Raw bone* contains moisture, fat, nitrogenous substances, etc., as well as phosphates, and in this state is hardly as useful as after the fat has been removed, since this fat retards the solution of the bone substance in the soil. The nitrogenous matter is, however, of great value as a source of nitrogen.

Bones may, however, receive special treatment. The fat may be extracted by solvents, leaving a more valuable fertilizer than the original bone, or both fat and nitrogenous matter may be removed by steaming or boiling. This leaves a product richer still in phosphorus, because of the removal of the substances containing none of that element. Tankage may include such cooked bone but also includes by-products of the packing houses.

In the refining of sugar large quantities of bone black are used. This is the product obtained by heating green bone without access of air, by which the organic matter of the bone is decomposed, volatile matter expelled, and a very finely divided carbon left deposited throughout the bone tissue. This bone black, pulverized to a suitable degree, is used for decolorizing syrups and other substances. After a time it is no longer useful in this way and the spent bone black is made into superphosphate.

The rock phosphates of this country occur chiefly in Florida, South Carolina and Tennessee. The mode of occurrence, physical state and percentage of phosphorus vary greatly. They are largely consumed in the manufacture of superphosphate, but are also well suited for application to land without other treatment than grinding. This raw phosphate is less easily assimilated by plants, but as the price is much lower it has been found, in some cases at least, that an equal expenditure will produce as great an increase in crops when the ground raw phosphate is used as is obtained by employing superphosphate made from the rock. As phosphates are not much subject to leaching out from soils it will be seen that from the standpoint of total amount of soil fertility added the raw phosphate might be much more economical.

Basic slag is sold under various names. It is obtained in the Thomas-Gilchrist method for the production of iron from ores containing phosphorus. In this lime is used which, combining with the phosphorus, produces a slag rich in that element, and which when finely ground is a valuable fertilizer. It scarcely reaches our state as yet, being produced mainly in European countries.

Apatite is a mineral occurring, mixed with other rock, in considerable quantities in Canada. It is present in minute crystals in many granite rocks and is probably the most important original source of the phosphates of soils. For use in fertilizers the Canadian apatite requires conversion into superphosphate.

The natural phosphates are only very slightly soluble and hence not easily taken up by plants. They are therefore not suitable for direct use as fertilizers where a strong, quick action is desired. They are usually rendered more soluble previous to use by being treated with sulphuric acid. The following equation expresses the result that takes place with calcium phosphate, whether it be the rock phosphate or the bone phosphate:

$$Ca_3(PO_4)_2 + 2H_2SO_4 = CaH_2(PO_4)_2 + 2CaSO_4.$$

It will be seen that the essential change consists in the exchange of calcium, Ca, and hydrogen, H. The compound $CaH_4(PO_4)_2$ is known to chemists as monocalcium phosphate or acid calcium phosphate, other names being also in use. The $CaSO_4$ is the same as burnt gypsum. The superphosphate of commerce contains these two substances mixed, and hence not only supplies phosphorus, but calcium, the characteristic metal of lime, limestone, and gypsum or land plaster.

When a superphosphate is applied to the soil, changes are likely to set in at once by which it tends to revert to the original nearly insoluble triphosphate, $Ca_3(PO_4)_2$. There is, however, a substance intermediate in composition, known to chemists as calcium diphosphate, as well as by other names. Since it is produced in soils by a process the reverse of that by which superphosphate was manufactured, it is in agriculture often designated as *reverted phosphate.* The following equations show two of the reactions by which the acid phosphate or superphosphate may be changed in the soil to the dicalcium phosphate or reverted phosphate, by the action of calcium carbonate from limestone, or by that of the insoluble triphosphate present:

$$\begin{array}{ccccccccc} \mathrm{CaH_4(PO_4)_2} & + & \mathrm{CaCO_3} & = & \mathrm{2CaHPO_4} & + & \mathrm{H_2O} & + & \mathrm{CO_2}. \\ \text{Monocalcium} & & \text{Calcium} & & \text{Dicalcium} & & \text{Water.} & & \text{Carbon} \\ \text{phosphate.} & & \text{carbonate.} & & \text{phosphate.} & & & & \text{dioxide.} \end{array}$$

$$\begin{array}{ccccc} \mathrm{CaH_4(PO_4)_2} & + & \mathrm{Ca_3(PO_4)_2} & = & \mathrm{4CaHPO_4}. \\ \text{Monocalcium} & & \text{Tricalcium} & & \text{Dicalcium} \\ \text{phosphate.} & & \text{phosphate.} & & \text{phosphate.} \end{array}$$

By other reactions, in some cases still more complex, compounds of iron and aluminum, present in all soils, cause the reversion of phosphates from the soluble monocalcium phosphate condition to the less soluble but still available dicalcium phosphate, and even to the still less valuable tricalcium phosphate. These less soluble phosphates are, however, by the action of carbonic acid in the soil slowly reconverted into available forms. This carbonic acid is produced in the decay of vegetable matter or humus of the soil. Other acids are also produced which contribute to the total dissolving effect upon the insoluble phosphates. Thus phosphorus in almost any form is a valuable constituent of soils and may at some time be brought into a condition in which plants may take it up even though after many years' delay. Phosphorus is one of the elements absolutely essential for plants, and the total amount present in a soil is of very great importance, and hence the total amount introduced in any fertilizer is second only in importance to the amount immediately available; that is, in the application of phosphate fertilizers the farmer naturally expects and desires immediate results, which are secured by the use of superphosphate, but at the same time if larger quantities of phosphates can be applied in other less soluble and available forms at the same expenditure, the ultimate value of the investment may be much greater, as the phosphorus will remain in the soil and be rendered available by slow natural processes.

Nitrogen.

The materials used as sources of nitrogen by the fertilizer manufacturer are quite varied. Most of these are of no immediate interest to the farmer. They may be classified in the two groups of *inorganic compounds* and *organic waste materials.*

The inorganic compounds are of three classes: *Nitrates, ammonium salts,* and *calcium cyanamide.* The organic waste most available in the West is that from packing houses, and consists of the *nitrogenous tissues* unfit for food, either from their inherent nature or because of the unwholesome condition of the animal. In the South *cottonseed meal* has been used as a fertilizer, but when in wholesome condition such use is wasteful in that the meal is a valuable feed, and when used as such the excretions of the animal contain a large proportion of the nitrogen, which may then be applied as a fertilizer, thus serving the double purpose of supporting both stock and land.

The principal nitrate used in fertilizers is *sodium nitrate* or *Chili saltpeter,* the old name for which is *nitrate of soda.* This important substance is found in large deposits of unknown origin occurring in the rainless regions of Chili and Peru. For use the crude natural substance is purified by extraction with water and recrystallization, and the commercial article is about 95 per cent pure and contains 15 to 16 per cent of nitrogen. The chemical formula is $NaNO_3$.

In the manufacture of gas by heating soft coal, considerable amounts of ammonia are produced from the nitrogenous plant residues still existing in the coal. In the purification of the gas for use in lighting, the ammonia is absorbed by the use of sulphuric acid, ammonium sulphate being produced. This is crystallized by evaporation of the solution in which it formed, and constitutes a concentrated source of nitrogen. The pure substance would contain over 21 per cent of nitrogen. Its chemical formula is $(NH_4)_2SO_4$.

Calcium cyanamide, $CaCN_2$, is a substance only recently used in fertilizing, and is made by passing nitrogen over heated calcium carbide. It seems likely to become a very important source of nitrogen for fertilizing land. Quite recently it has been found that nitrogen and hydrogen under great pressure and in the presence of osmium or uranium unite to form ammonia with such ease and rapidity that the process is exceedingly promising as a means of preparing compounds of nitrogen from the inexhaustible store of that element in the atmosphere.

Of the nitrogenous waste products of the packing houses a few may be mentioned in greater detail. Animals condemned for food purposes, and parts of others, including flesh, tendons and connective tissue, are treated to remove the fat, and then the residue is ground, and may be used in fertilizers if not suitable for cattle feed. Dried blood is similarly utilized. Hair, hoofs, horns, leather scraps, etc., contain high percentages of nitrogen and not infrequently are introduced into fertilizers. They are so slow to decay, however, that they are not in good repute for such use, though by special treatment their condition may be improved. In this state their use in commercial fertilizers is prohibited.

The fact may also be mentioned here that the organic residues of leguminous crops are an important source of nitrogen to soils, though not used in the preparation of commercial fertilizers. Nitrogen, though the element most quickly exhausted from a soil, is also the one most cheaply restored, since by the coöperation of clovers, alfalfa, peas, beans and other legumes with bacteria that grow upon their roots the abundant nitrogen of the air in the pores of the soil is brought into organic combination. This means of adding nitrogen to a soil must never be lost to view, and the purchase of nitrogenous fertilizers should be limited to the meeting of the special requirements of certain conditions or crops.

SOIL ANALYSIS WITH REFERENCE TO FERTILIZER REQUIREMENTS.

In the early history of Kansas no attention was paid to the composition of its soils except to boast of their inexhaustible fertility. The voice of the chemist has been lifted constantly, warning the people that this idea of possession of a fertility that is practically limitless is a delusion that can lead only to squandering of our natural resources, and to leaving posterity handicapped in the struggle for existence. To-day he is seeing his warnings justified. People in many localities of the eastern part of the state are making inquiry concerning chemical analysis of their soils with reference to learning what fertilizers should be applied and to what crops their soils are best adapted. A consideration of some of the aspects of this problem would seem to be timely.

The chemical composition of a soil is the most fundamental limit upon its usefulness. No matter what its depth, physical state or climatic environment, a soil that is actually deficient in one or more of the chemical elements essential to plant growth cannot be productive. Hence a thoroughgoing investigation of a soil cannot be made except it be on a chemical basis. However, the difficulties of a chemical investigation that shall lead to results that can be translated into definite statements concerning the special adaptation of a soil to a given crop, or into a prescription to meet its needs in the way of applications of fertilizers, are so great that at present they have been very incompletely surmounted.

All but a very small proportion of a soil is unavailable for the nutrition of plants and serves only for their mechanical support. The roots penetrate through to relatively great distances, both downward and sidewise, and thus the plant is anchored to a weight that enables it to stand upright. This mechanical function of a soil may be performed by material that is wholly inert in respect to nourishing the plant, or by material that to a certain extent is capable of undergoing changes whereby it becomes available. The nature of this more or less inert portion of the soil is thus of the greatest importance in respect to the endurance of its fertility. It can be readily seen that, if a chemical analysis of the total matter of a soil be made, and it be found wanting, the soil is hopelessly poor. It is, however, only with soils that consist almost entirely of quartz sand that such results would be obtained. On the other hand, the presence in a soil of adequate amounts of all the chemical elements essential to plants is no proof that the soil is fertile, since these elements may be in forms of combination such that plants cannot get them. Chemists have therefore sought for special means of analysis that will enable them to ascertain what amounts of the several elements are available to plants, rather than the total quantities of those elements.

No chemical means have yet been discovered that will test soils as a plant does. One difficulty in the way is that the different kinds of plants differ greatly in their power to acquire nutriment from a given soil. If by prolonged research a mode of investigation should be devised by means of which quantitative results could be obtained that would be proportional to the yields given by a certain crop, under otherwise favorable conditions, the results would not be completely applicable to other crops. This adds greatly to the complexity of the problem.

The nutriment that a plant gets from the soil enters it dissolved in the soil water. It might at first sight seem that simply ascertaining what amounts of the substances in a soil are soluble in water would disclose its crop-sustaining power. This is not the case, however. In the first place, if water be kept in contact with a soil until there is reason to believe that it is saturated, and it then be removed, a fresh addition of water will dissolve more from the soil, and a third amount will dissolve yet another portion. The soil may be treated indefinitely with these successive portions of water and continue to yield material which goes into solution. In the second place, it seems undeniable that the roots of plants influence the extent to which soil particles in contact with them are dissolved, by means of substances which pass from them to the soil. In this way some crops are enabled to extract more nutriment from a given soil than others can. Again, the presence of decaying organic matter, humus, in the soil, by its production of carbonic acid, increases the solvent power of the soil water, an effect that extends over years of time. For these reasons analysis of a water solution of a soil will not teach us what capacity for nourishing plants the soil possesses.

As plants have some specific solvent effect upon soils, chemists have attempted to find a solvent that will imitate their action. In this they have only partially succeeded. The use of a two-per-cent solution of citric acid, suggested by Dyer, has in many cases given consistent indications. In others the cultural experience has been at variance with what would be suggested by the analytical results. We have not thus far any solvent that will upon all soils give results that will be consistent with the yield returned by a single kind of crop, much less by all kinds, and it is not to be expected that such a solvent will ever be discovered. The conditions of absorption of plant food by the living cells of the rootlets are different from those presented by an indifferent substance. This is indicated, not only by recent observations on osmosis, but more simply by the fact that different kinds of plants growing together in the same solution or soil take up quite different quantities of the nutritive salts. This so-called selective action must determine that each kind of plant is for itself an independent case for investigation in respect to its relations to soil fertility and soil analysis.

Whatever may ultimately be accomplished in devising means of imitating the action of plants upon soils the results so obtained will indicate the immediate capacity of the soil rather than its aggregate fertility. As previously stated, soils may have a part of the chemical elements in such stable and insoluble combination as to put it entirely outside the probably more or less remotely available plant-food supply. Aside from this nearly insoluble part we have another that dissolves in moderately strong hydrochloric acid. What will dissolve in a few days in hydrochloric acid will dissolve in weaker acids, such as are found in soils containing humus, if a few years or centuries be given, and the amounts progressively dissolved be removed by the roots of plants. The ultimate quantities of the elements of fertility that can be utilized by crops is thus taken to be practically those that may be brought into solution by hydrochloric acid of specific gravity about 1.12. A chemical analysis of such a solution may be of great value in determining the probable permanent durability of a soil, and to a less extent its immediate capacity.

It has been found that any virgin soil that shows an ample supply of nutritive substances soluble in acid as described will be fertile provided that there are no greatly opposing influences in the physical condition of the soil or in the climate. With soils long under cultivation, however, by whatever means they may be analyzed results may be obtained that are more or less contradictory to cultural experience.

Soils may get into a condition of nonproductivity, the causes of which are obscure as yet. The influence of the previous cropping, whether different or the same, may greatly affect the yield of the present season. In some cases failures are traceable to fungus diseases with which the soil becomes affected. In other cases there is reason to believe that crops leave something in the soil that hinders the growth of succeeding crops of the same kind until it is removed. Some experiments by the bureau of soils have shown that in certain cases this condition seems to be corrected by the use of substances which do not themselves contain chemical elements of fertility. It is not impossible that a part of the beneficial effect of commercial fertilizers and barnyard manure is due to such action, though there can be no doubt that their effect is not limited to this, but that they supply needs of the crop in respect to chemical elements. The need of rotation of crops in order to maintain proper soil conditions is probably greater with many soils than is its need on account of any partial exhaustion of chemical elements.

The difficulty of drawing inferences concerning crop-producing power from chemical analyses only may be illustrated by referring to an experiment by Hilgard, in which a highly productive but heavy clay soil was mixed with one, three, four and five times its weight of purified sand. Plants were grown in a pot of the original soil, and in pots of soil of the four degrees of dilution by sand. It was found that up to and including the dilution with four times its weight of sand the plants made better growth in the diluted than in the original soil. Here, then, was an example of a soil mixture with only one-fifth as much of the nutritive elements, and these in the same ratios to each other as in the original soil, that gave even better results than the undiluted soil. In short, chemical composition is very important, but it is only one of the important considerations in respect to productivity.

Not only is the physical state of the soil an important factor in determining crop yield, but its depth, and the depth, composition and general character of the subsoil are of the greatest significance. Further, in respect to sampling a soil for analysis, if this be not properly done, so that the sample analyzed actually represents the land under investigation, the results of the analysis are worthless as a basis for any general conclusion.

It will be seen from the foregoing that a chemical analysis of a single soil sample may mean very little, but to be of any service it must be considered in connection with many other things. To be of the most use it should be possible to compare it with the results of analyses of adjacent uncultivated soils and of other soils in similar climatic environment. The physical conditions must also be carefully considered.

Partial analyses of soil directed toward answering definite limited questions are often very useful. Soils have been known to contain an abundance of nitrogen and yet to be deficient in that element in an available form. Organic matter may be so slightly decomposed as not to be in a condition to furnish nitrogen to crops, while the fully humified part can undergo nitrification promptly and thus supply this element, hence a distinction in the analysis between these two forms of nitrogenous matter may contribute much information. So, too, it has been found that phosphorus in humus is more available to the wheat crop than when in some other forms of combination.

So-called alkali soils are soils containing an excess of soluble mineral substances which do not in all cases give an alkaline reaction. An analysis of a soil with reference to excessive amounts of such mineral substances may be made a useful preliminary to any treatment to improve the condition. A qualitative analysis is certainly necessary, as the nature of alkali differs greatly and proper treatment of it cannot be prescribed without knowing the nature of the excessive salts present.

Some soils are deficient in lime, or, speaking more exactly, in calcium compounds, especially the calcium carbonate which is capable of neutralizing organic acids. A fertile soil for agricultural crops must be in a neutral or faintly alkaline condition. Analyses with reference to soil acidity are therefore often of much value. Independent of acidity leguminous crops, such as clover and alfalfa, require large amounts of calcium, and regions other than those in which limestone and gypsum are found may often require special investigation in respect to the calcium content of the soil.

PHYSICAL TESTS OF SOILS.

The limitations upon the extent to which chemical analysis can be used in forming a judgment upon soils has led to attempts to replace that mode of investigation by physical or mechanical analyses in which the size of the soil particles and in part the peculiarities of their mode of aggregation are studied. The relative dominance of certain sizes of particles in soils used largely for certain crops has been observed. However, the fact that the same crops may be quite successfully produced on soils of distinctly different mechanical composition makes this method of little practical use, however interesting a field of laboratory study it may be. The influence of rainfall, temperature, altitude, exposure and other climatic factors exceed physical constitution in their dominating position to a far greater degree than they do chemical composition. A suitable physical state may accompany an almost sterile condition. The sizes of the rock particles of a soil that has been exhausted by cropping are not materially different from what they were when the same soil was in its virgin state of fertility. At best the results of a physical examination of a soil are useless unless they are accompanied by the results of a searching chemical examination.

No kind of laboratory investigation of the physical properties of a soil possesses more than a small fraction of the value of observations upon the soil in place, with no more complicated equipment than one's eyes and hands and an auger. The lay of the land, the depth and texture of the soil and the depth and character of the subsoil are points that immeasurably exceed in importance any other physical characteristics.

INDICATIONS FROM NATURAL PLANT GROWTH.

Both chemical and physical investigation of soils in a laboratory way being limited in the usefulness of their results, these must be supplemented or in many cases replaced by observations upon the natural growth of trees, shrubs, grasses or weeds upon the soil, and by experiments in the production of plants or crops upon it. Let organic nature answer the question, What is this soil good for?

Observations concerning the natural plant growth upon a soil have always been used by practical men in judging of its value. The rich lands supporting a forest growth of oak, hickory, and other hard woods are in marked contrast with the poor, and even otherwise nearly barren, areas occupied by pines. The grasses of the rich prairies are very different in species and luxuriance from those of thin, alkaline, saline or otherwise unproductive regions. Even weeds seem to exercise a preference, and sand-bur land is very different from that best adapted to "pusley." This means of gaining an insight into soil values is one that, while used from time immemorial, is worthy of more extended study and application.

TESTS OF SOIL BY POT EXPERIMENTS.

Attempts to test soils as to their productiveness or their specific needs in the way of fertilizers have been made by means of experiments conducted in pots. The sizes of the pots used have varied from that of a capacity of a few ounces to one of several hundred pounds. Very valuable results have been obtained by this method, into the details of which space does not at present permit us to enter. It can readily be seen, however, that with climatic factors largely eliminated, and with a soil no longer in its natural state of aggregation or relation to subsoil, some of the most important features controlling crop yield are left out.

TESTING SOILS BY CROPS.

By far the best method yet devised for testing soils is by means of crops grown in the open field. Such experiments, in order to eliminate variations from season to season in rainfall and other climatic influences, should extend over a series of years to yield the best results attainable, but in a single year, if the season is not too abnormal, positive indications may be obtained. It is obvious that a soil may be deficient in but one or two of the essential chemical elements, and that in that case it would be a waste to purchase and apply fertilizers supplying elements not needed. Further, one may be disposed to apply to the soil an incomplete fertilizer, or an amendment that happens to be cheap or readily available, when in fact the soil is in need of something quite different. As a matter of economy, it is highly important that the farmer ascertain what is lacking in his soil before deciding upon the purchase of commercial fertilizers, or the kind to buy. The chemist cannot tell him with certainty what the soil needs, and no method has yet been devised that is equal to that of testing the land by means of crops that have been fractionally fertilized.

A test of this kind consists in laying off a series of plats on the soil in question, selecting an area as nearly uniform as possible, and applying different fertilizers to the several plats, leaving one or more unfertilized for comparison. The number of plats required depends upon the detail with which the test is to be made. Not less than four will suffice, and if this number is selected one plat will be left with no fertilizer, to one a potassium salt, to another a nitrogenous fertilizer, and to the other a phosphate must be applied. On comparing the crops obtained on the three fertilized plats with that given by the unfertilized one, the effect of potassium, nitrogen and phosphorus compounds separately applied will be ascertained. If it be found then that the nitrogen has increased the yield while the potassium and phosphorus have had but little if any effect, the conclusion must be that the soil is in need of nitrogen and not of the other two. If the plat receiving potassium shows an increased yield, a deficiency of that constituent of the soil will be indicated.

More comprehensive results are obtained by increasing the number of plats and including, in addition to those previously named, others to which nitrogen and potassium, nitrogen and phosphorus, phosphorus and potassium, and nitrogen, potassium and phosphorus compounds, respectively, are applied. In this case, too, it is well to add another plat, to be left without any fertilizer, making nine altogether. This arrangement will show the results of each of the three fertilizing constituents and of possible combinations of them.

There is one serious drawback to an experiment of this kind. Plat experiments which are designed to be exact duplicates have frequently been found to give considerably diverse results. For example, if in the field to be tested a series of nine plats were to be laid off and no fertilizer applied to any of them, the yields obtained from the several plats would not be the same, in all probability. This source of error can be avoided in two ways. The first is by testing the land for a few years without fertilizers, in order to ascertain the relative yields of the plats in their natural state. This is probably the best method as preliminary to a thorough investigation, but does not yield immediate results. The other method is to multiply the series of plats as many times as practicable and take the average result of the corresponding plats. Thus, if the series were repeated three times we would have the arrangement indicated by the accompanying diagram.

The average yield without fertilizers of the twenty-five plats will be shown by the average of plats 1, 9, 17 and 25, to which no fertilizer is applied, and the result will obviously be more reliable than if we should depend upon any one of these alone. Even if the total amount of land devoted to the experiment be no greater, these four plats represent the total area more truly than any four side by side do. So, too, the effect of a nitrogenous fertilizer alone will be shown with greater accuracy by taking the average yield of plats 2, 10 and 18 than would be the case by applying nitrogen to a single plat three times as large. The same considerations, of course, apply to all of the others, and the greater the number of repetitions of these series the more reliable the conclusions drawn from the results.

A PLAT FOR EXPERIMENTAL FERTILIZING.

1. Nothing.
2. Nitrogen.
3. Potassium.
4. Phosphorus.
5. Nitrogen and potassium.
6. Nitrogen and phosphorus.
7. Potassium and phosphorus.
8. Nitrogen, potassium, and phosphorus.
9. Nothing.
10. Nitrogen.
11. Potassium.
12. Phosphorus.
13. Nitrogen and potassium.
14. Nitrogen and phosphorus.
15. Potassium and phosphorus.
16. Nitrogen, potassium, and phosphorus.
17. Nothing.
18. Nitrogen.
19. Potassium.
20. Phosphorus.
21. Nitrogen and potassium.
22. Nitrogen and phosphorus.
23. Potassium and phosphorus.
24. Nitrogen, potassium, and phosphorus.
25. Nothing.

The interpretation of results obtained from such a series of plats is easy. Representing the entire series by the numbers of the first ones, it is obvious that if no material differences are noticed in the yields of the several plats, no fertilizers would be advantageous. If Nos. 2, 5, 6 and 8 showed increased yields not exhibited by any other plats, the necessary conclusion would be that the soil is in need of nitrogen, but not of anything else. If plats 2, 3, 6 and 7 showed increased yields, while plats 5 and 8 showed still greater increases, the conclusion would be that the soil is in need of both nitrogen and potassium, either of these alone producing a beneficial effect, but fertilizers containing both producing a still better result. If at the same time the plat receiving phosphorus only, showed little or no effect, and phosphorus with nitrogen, or with potassium, or with nitrogen and potassium, showed but little or no advantage over the plats receiving nitrogen alone, potassium alone, or nitrogen and potassium, respectively, it must be decided that phosphorus is not required by the soil. By similar lines of reasoning, any possible results may be interpreted, but for the greatest accuracy in such experimentation it is necessary to perform the preliminary experiments referred to, in which the relative yields of the several plats are ascertained through a series of years without the application of any fertilizers, and giving the plats strictly uniform treatment.

While these precautions are necessary for the most concordant and satisfactory conclusions, results of value may be obtained by the four-plat test first described, and no farmer can afford to spend much money for commercial fertilizers without having ascertained, by one or another of the plans above described, the actual needs of the soil. In carrying out a fertilizer test of this kind the plats should be long and narrow, rather than square, and one-tenth of an acre and upward in area.

The practical fertilizing test may, of course, be extended to include other points such as would require applications of calcium (lime) compounds or organic matter. In many cases of soils that have become unproductive or gotten out of condition the deterioration may be traced to the diminution of the humus or organic matter in them. Before deciding that commercial fertilizers are necessary, the effect of green manuring should be ascertained. It should also never be forgotten in this connection that barnyard manure, because of its content of organic matter in a state of decay, is superior to chemical fertilizers containing equal amounts of potassium, phosphorus and nitrogen compounds.

SUMMARY CONCERNING SOIL TESTING.

The preceding considerations may be summarized briefly. A thorough chemical analysis of a soil is indispensable to any comprehensive study of its condition and probable durability. Such chemical analysis may not be sufficient alone to give positive indications concerning the present productiveness of the soil, or its needs in respect to fertilizers. Chemical investigation directed toward certain specific points may be of great value in respect to a given soil. Laboratory tests of a purely physical character afford little if any information that cannot be obtained better by examination of the soil in its natural condition and position. The immediate fertilizer requirements of a soil are best ascertained by means of systematic fractional fertilization of different crops.

FERTILIZER REQUIREMENTS OF DIFFERENT CROPS.

Among the questions most frequently asked of experiment stations, agronomists and agricultural chemists are those requesting information concerning the kind of fertilizers and amount to be used for corn, wheat, potatoes, etc. Answering such questions is by no means simple. It requires not only knowledge concerning the composition of the mineral substances normally present in the crop under consideration, but the chemical characteristics of the soil should be known. The difficulty of ascertaining the latter is treated elsewhere in this bulletin. It is not the present purpose to deal minutely with the question of the fertilizer needs of specific crops. Those requiring detailed information should secure one or another of the excellent books available on the subject, such as "Fertilizers," by Director Voorhees of the New Jersey Experiment Stations, or "Soils and Fertilizers," by Professor Snyder, until recently chemist of the Minnesota station.

In the use of fertilizers there are some general principles which, if understood, are of great aid in making decisions concerning their choice, and in modifying one's practice after an experimental trial.

Each plant normally has a certain life cycle to pass through leading to the perpetuation of the species by the production of seed or other organs of propagation, such as tubers, bulbs, etc. Man in his utilization of plants looks upon them in part from a totally different point of view from that which the plant would have, if it could have any. That is, while from the viewpoint of plant physiology the continuation of the species is all-important, in the utilization of plants by the farmer their adaptation as food is the chief consideration, and reproduction is of interest only as a means of getting more food.

The part of the plant used as food may be the seed, in which case the interests of the plant species and of the farmer are identical; or it may be the vegetative portion of the plant, the part which grows and elaborates the material put into the seed. In the latter case man may so favor this vegetative function as to impair seriously the seed production. He may also by unwise choice of fertilizers defeat his purpose to obtain seed and get instead a luxuriant growth of leaves and stems.

The maturation of plants with the production of seed is accompanied by retardation and cessation of growth in other respects. This seems to be induced in part by an accumulation of insoluble matter in the tissues. For example, cereals may be grown successfully, as far as the plants are concerned, in the absence of silica, but seed is produced with difficulty, or not at all, under those conditions, notwithstanding the fact that silica is present in the seed in but very small amount while abundant in the stems of the normally grown crops. The presence of the silica in the leaves, stems, etc., of the plants seems to be necessary as a check to growth in order to initiate the reproductive processes.

Nitrogenous manures act upon plants in a special manner. Nitrogen being a nonmetal and entering into combination in soluble inorganic salts, or in organic constituents of plant tissues, it does not necessarily accumulate as an insoluble ash-constituent in the plant cells. If the element is brought to the plant as an ammonium salt it carries with it no metal to be similarly disposed of. If taken up as a nitrate it would be accompanied by some metal which would accumulate in the tissues as some mineral salt, but the accumulations of such salts would be less rapid than if the same amount of metal were taken in in the form of sulphate, phosphate, silicate, etc.

From the causes indicated above, as well as from the preeminent position occupied by nitrogen as a constituent of protein in plants, we see ample explanation for the observed fact that nitrogenous fertilizers cause a luxuriant growth of stems and leaves, but if present in excess are liable to result in little or no seed. The effects of drainage from manure piles are frequently noticeable in this way. In the case of grasses which are grown for forage and not for seed nitrogenous fertilizers are thus seen to be especially applicable. The long-continued experiments of Lawes and Gilbert, Rothamsted, England, have shown most strikingly the effect of nitrogen on grasses. Where large applications of nitrates or ammonium salts have been applied the other orders of plants have been almost completely suppressed while the true grasses have made an immense tonnage.

Though excessive use of nitrates or ammonium salts is liable to cause scanty seed-formation, a liberal amount contributes more than all other fertilizing elements to an abundant harvest of wheat, corn, oats, etc., crops which botanically are members of the great order of the grasses.

The dominant position of nitrogen in producing large wheat yields has also been most convincingly shown by Lawes and Gilbert. They made experiments, which are being continued at the present time, in which mineral fertilizers alone were applied, different quantities of nitrogen in nitrates or ammonium salts, and nitrogen compounds and mineral substances together. The accompanying table exhibits some of the results.

TABLE II. Wheat sixty years in succession on the same land (Rothamsted). Fertilizers used annually. and average yield of grain in bushels per acre, for fifty-three years, 1852 to 1904.

Plat.		Bushels.	Increase.
3-4	Unmanured	12.8	.....
2B	14 tons farmyard manure since 1843	35.3	22.5
5	392 lbs. calcium superphosphate, 200 lbs. potassium sulphate, 100 lbs. sodium sulphate, 100 lbs. magnesium sulphate,	14.7	1.9
10	400 lbs. ammonium salts (86 lbs. nitrogen)	20.4	7.6
7	Same fertilizers as 5 and 10 combined	32.6	19.8
11	400 lbs. ammonium salts (86 lbs. nitrogen), 392 lbs. calcium superphosphate,	23.6	10.8
12	Same as 11, and 366 lbs. sodium sulphate	29.5	16.7
13	Same as 11, and 200 lbs. potassium sulphate	31.2	18.4
14	Same as 11, and 280 lbs. magnesium sulphate	29.7	16.9

Study of the table shows how little use it is to apply only mineral fertilizers to wheat when the soil is inadequately supplied with nitrogen. This element is stored in soils in the organic matter, and from this soluble compounds are slowly produced. Kansas farms have, in the older parts, been robbed of this organic matter and it is probable that the soil nitrogen is at present the limiting factor in grain production.

It must not be at once concluded that if nitrogen be lacking the farmer should buy nitrogenous fertilizers. The chief natural source of soil nitrogen has been the leguminous plants. For countless centuries the wild plants of this order, including peas, beans and clovers, were growing on the prairies, and with the coöperation of microscopic organisms growing on their roots accumulated the nitrogen that Kansas farmers have been exploiting. The farmer must learn a lesson from nature and repair the damage to his soil by cultivating alfalfa, clovers, etc., and seeing that the nitrogen that they accumulate gets back to the soil. Considerable amounts will be in the roots and stubble, but much more is in the leaves and stems. If these be sold from the farm in the form of hay, the land not only gets no benefit from the nitrogen contained in it, but it is further impoverished by the loss of potassium, phosphorus, calcium and other elements taken up by the plants and contained in the hay.

Permanent maintenance of fertility demands that the animal excretions produced when the farm crops are fed be returned to the land. In so far as this is not done the soil must depend on the disintegration of mineral constituents, and in many cases these are so limited in amount that the production of sterility is only a question of time.

It is a widely spread error to suppose that the production of clover or alfalfa on land is a general fertilizer for it. These crops add to the stock of nitrogenous compounds, but they diminish the stock of mineral substances.

In respect to the total amount of nitrogen required, the corn crop makes heavier demands than the wheat crop. It can, however, flourish with less available nitrogen in the soil in the spring, as its period of growth extends over a longer time and there is opportunity for the production of nitrates from the organic matter of the soil during the summer months.

The preceding paragraphs are chiefly in reference to the true grasses, including cereals. When we consider leguminous plants, such as peas, beans, alfalfa, and clovers of all kinds, the basic principles to be considered are quite different. These crops, with the assistance of the bacteria growing upon their roots, are largely independent of the soil in respect to nitrogen, and mineral fertilizers, therefore, must be chiefly considered. Calcium or lime compounds are of great importance to them. No other crop removes so large an amount of lime from the soil as does alfalfa. In soils not amply provided through limestone or gypsum with an abundance of calcium, the application of these substances to alfalfa and clover may be of vital importance. In this connection it may borne in mind that superphosphate is a calcium compound, so that when it is applied to land a double fertilizing function is performed.

For the purpose of adding calcium, slaked lime, air-slaked lime, ground gypsum or ground limestone may be used. If lime is added it will be somewhat caustic at first and may act upon organic matter and possibly mineral matter, but in a short time it will be transformed to calcium carbonate, the chief constituent of limestone.

The ash of potatoes is rich in potassium, and in fertilizing this crop this should be borne in mind and a preponderance of that element provided in the fertilizer applied. Similar fertilizing is applicable for many other garden crops. As the profit in truck gardening lies largely in the production of early and succulent vegetation, there is in this state probably no line of farming in which commercial fertilizers can be more profitably employed. As light sandy soil supplies the texture needed for the production of such crops most easily, it is also most likely to be in need of additional fertility, as such soils are liable to be deficient in soluble substances and nitrogen.

In the manuring of fruit trees and orchards it must be borne in mind that too liberal a supply of fertilizer is liable to result in the production of wood rather than fruit. For nursery stock this would be no disadvantage provided that the growth produced is not so rank as to produce soft, imperfectly matured wood. With fruiting orchards, mineral fertilizers are often of great assistance, but an excess of nitrogen should be avoided.

The New York Experiment Station (Geneva), in its Bulletin No. 94, issued a valuable compilation of information concerning fertilizers and the requirements of various crops in this respect. The practical discussion of these data adds much to its usefulness. By the courtesy of Prof. L. L. Van Slyke, author of the bulletin, we are permitted to make use of some of the material in it. The accompanying table is a rearrangement, and, in respect to phosphorus and potassium, a recalculation and adaptation of data presented in that bulletin, and thankful acknowledgment of our indebtedness is tendered at this time. Such estimates are very useful, but must be recognized as only approximations. Our experience with fertilizers, thus far, in this state has not been sufficient to afford a basis for recommendations, and those of Van Slyke are offered as a valuable convenience, for use until local observations shall suggest modifications. The figures given cover the range between a moderate application and a very heavy one.

Table III. Showing in pounds per acre the quantities of the elements suggested for use in available form, in fertilizers for the crops indicated.

Crops.	Nitrogen.	Phosphorus.	Potassium.	Crops.	Nitrogen.	Phosphorus.	Potassium.
Alfalfa	5-10	12.5-25	30- 60	Lettuce	40-80	20-40	60-120
Apples	8-16	12.5-25	40- 80	Millet	15-30	12.5-25	30- 60
Asparagus	20-40	12.5-25	30- 60	Muskmelons	30-60	20-40	50-100
Barley	12-24	8.5-17	20- 40	Nursery stock	10-20	10-20	25- 50
Beans	5-10	12.5-25	30- 60	Oats	12-24	8.5-17	25- 50
Beets	20-40	10-20	30- 60	Onions	45-90	25-50	70-140
Blackberries	15-30	12.5-25	30- 60	Parsnips	20-40	25-50	40- 80
Buckwheat	15-30	12.5-25	30- 60	Peaches	15-30	17.5-35	45- 90
Cabbage	40-80	30-60	75-150	Pears	8-16	12.5-25	40- 80
Carrots	15-30	15-30	35- 70	Peas	5-10	12.5-25	30- 60
Cauliflower	40-80	30-60	75-150	Plums	10-20	15-30	35- 70
Celery	40-80	20-40	50-100	Potatoes	30-60	17.5-35	55-110
Cherries	10-20	15-30	35- 70	Pumpkins	30-60	20-40	50-100
Clover	5-10	12.5-25	30- 60	Quinces	8-16	12.5-25	40- 80
Corn	10-20	15-30	25- 50	Radishes	15-30	15-30	35- 70
Cucumbers	30-60	20-40	50-100	Raspberries	12-24	17.5-35	50-100
Currants	10-20	10-20	30- 60	Rye	12-24	8.5-17	25- 50
Egg plant	40-80	20-40	75-150	Sorghum	10-20	15-30	25- 50
Flax	10-20	10-20	25- 50	Spinach	15-30	25-50	35- 70
Gooseberries	10-20	10-20	30- 60	Squashes	30-60	20-40	50-100
Grapes	8-16	12.5-25	35- 70	Strawberries	25-50	25-50	60-120
Grass for pastures	15-30	12.5-25	30- 60	Tobacco	30-60	20-40	60-120
Grass for lawns	20-40	10-20	25- 50	Tomatoes	25-50	15-30	30- 60
Grass for meadows	15-30	12.5-25	30- 60	Turnips	20-40	10-20	30- 60
Hops	20-40	15-30	80-160	Watermelons	30-60	20-40	50-100
Horse-radish	15-30	10-20	30- 60	Wheat	12-24	8.5-17	10- 20

THE VALUATION OF FERTILIZERS.

The cost of fertilizers varies considerably, depending upon distance from the source of supply, labor expended in their preparation, interest on capital, profit of dealers, etc. Not only does the price of a given material vary, but the cost of a particular element varies, depending on the mode of combination in which it is purchased. This is due in part to the greater availability of the element in certain forms over that of others, and the consequent difference in esteem in which the several forms are held.

Since the relative adaptability of a given element in the different compounds in which it may be obtained is not the same for all crops, it will never be possible to calculate exactly the relative value of the element in these different forms. For the sake of making approximate comparisons, however, chemists for many years have been making estimates of the value of fertilizers. The chemists and directors of several experiment stations agree annually upon the valuation to be used for the current year. By means of these valuations it is possible to calculate approximately the relative worth of the various brands of fertilizers on the market and to avoid the purchase of those which are evidently deficient in value for the price asked.

The valuations adopted are based upon the selling price on the Atlantic seaboard of the raw materials from which fertilizers are manufactured, and hence do not include any of the cost of manufacture. The valuation adopted for 1910 by the experiment stations of Maine, Vermont, Massachusetts, Rhode Island and Connecticut are shown in the accompanying table. For New Jersey the valuations are the same with one slight exception made necessary by a legally prescribed difference in the mode of analysis of phosphates.

TABLE IV. Showing schedule of trade values for 1910.

	Cents per pound.
Nitrogen in nitrates	16
Nitrogen in ammonium salts	16
Organic nitrogen in dry and fine-ground fish, meat and blood and in mixed fertilizers	20
Organic nitrogen in fine bone and tankage	20
Organic nitrogen in coarse bone and tankage	15
Phosphorus in water-soluble phosphates	10.3
Phosphorus in ammonium citrate-soluble phosphates and in fine-ground bone and tankage	9.16
Phosphorus in coarse bone and tankage, cottonseed meal, castor pomace and ashes	8.02
Phosphorus in phosphate insoluble in ammonium citrate, mixed fertilizers	4.58
Potassium in high-grade potassium sulphate and in forms free from chlorides (muriates)	6.02
Potassium in potassium chloride (muriate)	5.12

The valuations shown for phosphorus and potassium have been calculated from the round numbers adopted for "phosphoric acid" and "potash." For all practical purposes, the figures given above may be rounded off to the nearest tenth.

The meaning of these valuations must not be mistaken. They are based on the cost of materials, not on the returns that they yield in crops. The return received following the use of a fertilizer depends on many things beside the fertilizer itself. Among the most important of these is the crop treated. A crop which sells at a low price will return a much smaller additional profit for a certain weight of increased yield than will a crop which sells at a high price. Furthermore, the farmer may at considerable expense use a fertilizer that is not especially adapted to the requirements of the crop to which it is applied. Again, he may apply certain constituents to a soil already well supplied with them, and then not even get an additional yield. The returns attending the use of a fertilizer are thus seen to be dependent upon the business intelligence of the user, and this must be applied to all phases of the problem, not merely to a consideration of the fertilizer.

THE FERTILIZING CONSTITUENTS OF CROPS.

The fact that crops carry off considerable amounts of potassium, nitrogen, phosphorus, etc., is the chief reason why, in many places, it is necessary to add these elements to the soil. Western farmers are all too frequently altogether ignorant or indifferent in respect to the fertilizer valuations represented in their crops, the actual money outlay that would be required to return to the soil in commercial forms the elements removed by them.

The amount removed by a crop cannot be accurately calculated, as plants vary in composition from several causes, the composition of the soil being one. Several chemists have made estimates based on available data. These differ considerably, but most of the accompanying table gives figures that have been calculated from one published by Snyder.

To these we have added a column showing what the indicated quantities of potassium, nitrogen and phosphorus would cost if purchased in fertilizers. For this calculation we have used the valuations previously presented for these elements.

TABLE V. Pounds per acre and value of plant food removed by certain crops.

CROPS.	Gross yield, lbs.	Nitrogen.		Phosphorus.		Potassium.		Calcium.		Silica.	Total ash.	Total value of nitrogen, phosphorus & potassium
		Lbs.	Cost.	Lbs.	Cost.	Lbs.	Cost.	Lbs.	Cost.			
Wheat, 20 bu	1,200	25	$5 00	5 46	$0 44	5.81	$0 35	0 71	$0.004	1.0	25	$5 79
Straw	2,000	10	2 00	3.27	26	23.24	1 40	5.00	.025	115.0	185	3 66
Total		35	7 00	8.73	70	29 05	1 75	5.71	.029	116.0	210	9 45
Barley, 40 bu	1,920	28	5 60	6.55	52	6 60	40	0 71	.004	12 0	40	6 52
Straw	3,000	12	2 40	2.18	17	24 90	1 50	5 71	.028	60 0	176	4 07
Total		40	8 00	8.73	70	31 50	1 90	6.42	.032	72 0	216	10 59
Oats	1,600	35	7 00	5.24	42	8.30	50	1.07	.005	15 0	55	7 92
Straw	3,000	15	3 00	2 62	21	29 10	1 75	6.78	.034	60 0	150	4 96
Total		50	10 00	7 86	63	37 40	2 25	7.85	.039	75.0	205	12 88
Corn, 65 bu	2,200	40	8 00	7 86	63	12 45	75	0.71	004	1 0	40	9 38
Stalks	3,000	35	7 00	0 87	07	37 35	2 25	7.85	.039	89 0	160	9 32
Total		75	15 00	8.73	70	49.80	3 00	8 56	.043	90.0	200	18 70
Peas, 30 bu	1,800	......	....	7 86	63	18.30	1 10	2 85	.014	1.0	64	1 73
Straw	3,500	......	....	3.06	25	31.50	1 90	150.71	.754	9 0	176	2 14
Total		......	....	10 92	87	49 80	3 00	153 56	.768	10.0	240	3 87
Mangels, 10 tons	20,000	75	15 00	15.28	1 22	12 45	75	21 42	.107	10 0	350	16 97
Meadow hay, 1 ton	2,000	30	6 00	8.73	70	37 40	2 25	8.59	.043	50.0	175	8 95
Clover, 2 tons	4,000	......	....	12 23	98	54 80	3 30	53 57	.268	15.0	250	4 28
Alfalfa, 4 tons	8,000	......	....	13 75	1 10	200.80	12 09	85.44	.427	....	....	13 19
Potatoes, 150 bu	9,000	40	8 00	8 73	70	62 30	3 75	17 85	.089	40.0	125	12 45
Flax, 15 bu	900	39	7 80	6 55	52	6 60	40	2.14	.011	0.5	34	8 72
Straw	1,800	15	3 00	1.31	11	15.80	95	9 29	.046	3.0	53	4 06
Total		54	10 80	7 86	63	22.40	1 35	11.43	.057	3.5	87	12 78

FERTILIZING ELEMENTS IN THE FOOD CONSUMED BY DOMESTIC ANIMALS.

From the data presented in table V it is evident that considerable quantities of the important elements of soil fertility are contained in the food consumed by domestic animals. The actual commercial value of this is not fully realized by most farmers, and the value of farm manures as compared with commercial fertilizers is not appreciated.

The percentages of fertilizing elements in farm manures vary greatly, depending upon the care with which they are protected, the character of the feed consumed by the animals and the extent to which rotting has progressed or water evaporated. The figures for the fertilizing constituents are always low, but they are present in readily available form and the accompanying organic matter has itself a highly beneficial effect on the land. Even with these low percentages the total amount of plant food in the manure produced on a farm reaches very significant quantities. The following table has been calculated from the observations of several different men and may serve to bring out strongly the value of this neglected farm product:

Table VI. Fertilizer constituents voided by one animal per annum, and value, taking nitrogen at 20 cents, phosphorus at 8 cents, and potassium at 6 cents per pound.

		Nitrogen.	Phosphorus.	Potassium.	Value.
Horse,	Amount	125 20	20 90	35.90	
	Value	$25 04	$1.67	$2 15	$28.86
Cow,	Amount	170 60	11 40	89 30	
	Value	$34 12	$0.91	$5 36	40 49
Sheep,	Amount	8 40	2 40	11 90	
	Value	$1.68	$0 19	$0 71	2 58
Pig,	Amount	11 90	4 60	9 90	
	Value	$2 38	$0 37	$0 59	3.34

CHOOSING FERTILIZERS.

After a farmer has decided to try the effect of commercial fertilizers upon a given crop the problem of deciding upon the ones to be used is likely to present considerable difficulty. The tables given in this bulletin are designed to reduce the work in this connection to a minimum, but it must be recognized that the use of fertilizers is an application of science in agriculture, and to do this economically and with profitable results requires intelligent thought. Table III shows approximately the quantities of the several elements that may be used, but specific knowledge of the deficiencies of one's soil as shown by analysis or by test crops may point directly to important modifications of those figures.

Furthermore, it may be difficult to choose from among the fertilizers registered in this state, and especially the limited number on sale in one's own town, one that will contain the nitrogen, phosphorus and potassium in the proper proportions. From these points of view it is not infrequently advantageous to the farmer to buy fertilizers containing the elements which he desires and mix them himself. Possibly one of the ready-mixed fertilizers available may be modified by mixing with it a certain amount of one or more other fertilizers, thereby bringing the amounts of the several constituents to the desired relation. In making such calculations table VII will often be found extremely useful.

MIXING FERTILIZERS AT HOME.

If, by means of test crops or otherwise, the farmer has arrived at a definite conclusion concerning the fertilizer that he wishes to apply, it may be almost necessary for him to purchase the raw materials and mix them himself. If so he should bear in mind that they should be as finely ground as practicable and that he must mix them with extreme care if the product is to fulfill his expectations. Unless a uniform mixture is made the several constituents of the fertilizers will not be distributed in the same relative amounts over his fields. Unless they are finely ground they cannot be perfectly mixed, nor uniformly distributed through the soil, and hence the crops cannot profit by them to the same extent.

For mixing fertilizers on the farm all that is required is a smooth floor, shovels, and a screen of three or four meshes to the linear inch. The fertilizers purchased, though they may have been finely ground, are liable to pack in the bags and become lumpy. The rather coarse screen specified is for the purpose of separating these lumps, which must be pounded up until all will pass the screen.

In mixing, the most bulky of the fertilizers is first spread out evenly on the floor in a layer a few inches thick. The next in bulk is then spread evenly over this, and so on until all are spread out. The mass is then shoveled to one side in a ridge or pyramid in such a manner as to mix the different parts as much as possible. The shoveling is repeated two or three times, making three or four shovelings of it all together.

Analyses made of home mixtures so prepared have shown that satisfactory uniformity in composition may be obtained, and field experiments with such fertilizers have given results equal to those afforded by factory-mixed fertilizers of the same composition. The saving in cash outlay is considerable and is well worth attention. One should not undertake home mixing, however, unless equipped to do the work properly and willing to give it sufficient attention to see that it is well done.

FUNDAMENTAL COMMERCIAL FERTILIZERS.

In the preparation of mixed fertilizers, either by large manufacturers or by the farmer for his own use, certain substances are available in considerable quantities. For the convenience of the farmer.a table is given herewith showing the composition of these that he may have something to guide him in choosing. The different ones are grouped according to the element for which the fertilizer is employed, chiefly, though it will be seen that some contain more than one element and all must be taken into account in calculating the formula for a mixed fertilizer. The figures for commercial fertilizers are calculated from a table published by Voorhees in Farmer's Bulletin No. 44, United States Department of Agriculture. A statement concerning the composition of farm manures is also included for comparison and for general reference. Farm manures vary enormously in composition, depending to a certain extent on the species of the animal, but more on the feed of the animal, the amount of water in the manure, the amount of bedding, whether or not both solid and liquid excretions are included, and the extent to which fermentation has taken place. The figures given are the average of selections made from Storer's compilation, and apply to fresh or nearly fresh manures, free from litter. As an average for well-kept mixed barnyard manure from cattle, one may without serious error assume a composition of 0.5 per cent nitrogen, 0.14 per cent phosphorus and 0.42 per cent potassium. A similar product from horses may be taken as containing 0.5 per cent nitrogen, 0.11 per cent phosphorus and 0.40 potassium.

TABLE VII. Showing composition of principal commercial fertilizing materials and farm manures.

	Nitrogen.	Phosphorus in—			Potassium.	Chlorine.
		Available phosphates.	Insoluble phosphates.	Total phosphates.		
NITROGENOUS.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Sodium nitrate (Chili saltpeter, nitrate of soda)	15.5 to 16.0					
Ammonium sulphate (sulphate of ammonia)	19.0 to 20.5					
Dried blood, high grade	12.0 to 14.0					
Dried blood, low grade	10 0 to 11.0			1.3 to 2.2		
Concentrated tankage	11.0 to 12.5			0.4 to 0.9		
Bone tankage	5.0 to 6.0			4.8 to 6.1		
Dried fish scraps	7.0 to 9.0			2.6 to 3.5		
Cottonseed meal.	6.5 to 7.5			0.6 to 0.9	1.7 to 2.5	
Castor-bean pomace	5.0 to 6.0			0.4 to 0.6	0.8 to 1.2	
PHOSPHATIC.						
South Carolina rock phosphate			11.4 to 12.2	11.4 to 12.2		
South Carolina rock superphosphate (dissolved S. C. rock phosphate)		5.2 to 6.5	0.4 to 1.3	5.7 to 7.0		
Florida land rock phosphate			14.4 to 15.3	14.4 to 15.3		
Florida pebble phosphate			11.4 to 14.0	11.4 to 14.0		
Florida superphosphate (dissolved Florida phosphate)		6.1 to 7.0	0.4 to 1.7	7.0 to 8.7		
Bone black			14.0 to 15.7	14.0 to 15.7		
Bone black superphosphate (dissolved bone black)		6.5 to 7.4	0.4 to 0.9	7.4 to 7.9		
Ground bone	2.5 to 4.5	2.2 to 3.5	6.5 to 7.4	8.7 to 10.9		
Steamed bone	1.5 to 2.5	2.6 to 3.9	7.0 to 8.7	9.6 to 12.7		
Dissolved bone	2.0 to 3.0	5.7 to 6.5	0.9 to 1.3	6.5 to 7.4		
Thomas slag				5.0 to 10 0		

Potassic.						
Potassium chloride (muriate of potash)	......	......	......	......	41.5	45.0 to 48.0
Potassium sulphate, high grade (sulphate of potash)	......	......	......	......	39.8 to 43.2	0.5 to 1.5
Potassium magnesium sulphate (sulphate of potash and magnesia)	......	......	......	......	21.6 to 24.9	1.5 to 2.5
Kainite	......	......	......	......	10.0 to 10.4	30.0 to 32.0
Sylvinite	......	......	......	......	13.3 to 16.6	42.0 to 46.0
Cottonseed-hull ashes	......	......	......	3.1 to 3.9	16.6 to 24.9	......
Wood ashes, unleached	......	......	......	0.4 to 0.9	1.7 to 6.6	......
Wood ashes, leached	......	......	......	0.4 to 0.6	0.8 to 1.7	......
Tobacco stems	2 0 to 3.0	......	......	1.3 to 2.2	4.2 to 6.6	......
Farm Manures.						
Cattle dung	0.40	0 09	......	0.09	0.17	......
Horse "	0 58	0.16	......	0.16	0.43	......
Poultry "	1.60	0.65	......	0.65	0.71	......
Sheep "	0.63	0.17	......	0.17	0.87	......
Swine "	0.61	0.16	......	0.16	0.82	......
Cattle urine	0.90	0.006	......	0.006	1.10	......
Horse "	1.70	trace	......	trace	1.05	......
Sheep "	1.20	0.013	......	0.013	1.05	......
Swine "	0.43	0.05	......	0 05	0.38	......

HOW TO CALCULATE THE QUANTITIES OF FERTILIZERS TO BE APPLIED.

Unless previous plot testing has shown the nature of the deficiency in one's soil, the quantities of nitrogen, potassium and phosphorus to be applied to the several crops may be determined by consulting table III. For example, the amounts recommended for potatoes are: 30 to 60 pounds of nitrogen, 17.5 to 35 of phosphorus and 55 to 110 of potassium.

These elements, however, cannot be applied as such, and would be useless or injurious if so applied. Plants get them in various compounds, such as nitrates, ammonium salts, organic waste products, phosphates, potassium salts, etc. These substances as they occur in commerce vary considerably in their content of the desired constituents, and certain arithmetical calculations are necessary in order to ascertain the quantities of any one to be used to apply the desired amounts of nitrogen, potassium or phosphorus, as the case may be. While these calculations are not difficult, table VIII has been prepared that the labor of making them may be reduced to a minimum.

Suppose that it has been decided to apply fertilizers carrying 45 pounds of nitrogen, 26 of phosphorus and 80 of potassium in available forms. These amounts might be supplied by various substances as shown by table VII. The calculation is simplest if the materials chosen are such that each furnishes but one of the fertilizing elements. For example, sodium nitrate might be chosen to supply nitrogen, Florida superphosphate for phosphorus and potassium sulphate for potassium. Their composition may, for illustration, be assumed to be 15.8 per cent nitrogen in the nitrate, 7 per cent available phosphorus in the superphosphate, and 42.2 per cent potassium in the potassium sulphate.

By referring to table VIII, in the columns marked "percentage present" one finds the numbers 15.8, 7.0 and 42.2, and opposite these to the right, in columns headed "pounds required," he finds the corresponding weights necessary to furnish one pound, viz., 6.33 pounds of the sodium nitrate for one pound of nitrogen, 14.3 pounds of the superphosphate for one pound of phosphorus, and 2.37 pounds of the potassium sulphate for one pound of potassium. The total amount of each required is found by multiplying the amount that contains one pound by the pounds of the element required in each case. Thus:

6.33 × 45 = 284.9 sodium nitrate,
14.30 × 26 = 371.8 superphosphate,
2.37 × 80 = 189.6 potassium sulphate.

If, however, one wishes to use dissolved bone as the source of the phosphorus he must take account also of the nitrogen in it. Suppose that it contains 2.5 per cent of nitrogen and 6.4 per cent of phosphorus in available form. A little thought will show that although it contains nitrogen it cannot be used as the sole source of that element without adding much more phosphorus than desired, for it is proposed to apply 45 of nitrogen and 26 of phosphorus, or nearly twice as much nitrogen as phosphorus, while in the dissolved bone there is over twice as much phosphorus as nitrogen.

The first step then is to compute the amount of the dissolved bone necessary to furnish the 26 pounds of phosphorus. By reference again to table VIII one finds that with a percentage of 6.4, 15.6 pounds will be required to give one pound of phosphorus. The total weight required would be 15.6 × 26 = 405.6 pounds. As this contains 2.5 per cent of nitrogen, the quantity of that element contained in the bone is found by multiplying by the rate per cent and dividing by 100. Thus, $\frac{405.6 \times 2.5}{100} = 10.14$, which is the number of pounds of nitrogen in the 405.6 pounds of bone. As the total nitrogen to be applied is 45 pounds, 45 — 10.14 = 34.86, the number of pounds to be supplied by other means. This might be by a concentrated tankage carrying 12.5 per cent of nitrogen. By means of table VIII it is seen that of such tankage eight pounds will be needed to supply one pound of nitrogen. To supply 34.86 pounds, 34.86 × 8 = 278.88 pounds will be required.

If now we suppose that the potassium is to be furnished by means of unleached wood ashes containing 5.9 per cent of potassium, we see by table VIII that 17 pounds of the ashes will be necessary for each pound of potassium to be supplied. Hence 80 × 17 = 1360 is the number of pounds required with the 405.6 pounds of dissolved bone and 278.88 pounds of concentrated tankage, to supply 80 pounds of potassium, 26 of phosphorus and 45 of nitrogen. The bone and tankage also carry small quantities of phosphorus in forms not rated as available, but which are of value, as natural processes will gradually change them to available compounds.

On principles similar to those illustrated above the quantities required of any fertilizers chosen may be computed, and any desired amounts of nitrogen, phosphorus and potassium supplied in the mixture thus calculated.

FILLER IN FERTILIZERS.

There is likely to be an important misconception in reference to the amount of inert material in fertilizers as sold. Thus if a fertilizer is guaranteed to contain 7 per cent phosphorus, 8 of potassium and 4 of nitrogen, the first impression must be that the remaining 81 per cent is unnecessary "filler." The farmer may think that he is being cheated as to quality, and in any event is obliged to pay freight on worthless material. This view may at times or to a certain extent have a real justification, but it may be unfounded for the most part. Let us see how this comes about.

The elements phosphorus, potassium and nitrogen are never used in the pure, free state as fertilizers. Nitrogen is a gas, and abundantly present in the air but cannot be appropriated by any field crops except the legumes. Phosphorus and potassium would be wholly unfit to apply to land in the free state, and are very costly to prepare from their compounds even if the elements themselves as such were suitable to put on the soil. These elements are merely the measures of value of the considerable variety of their compounds present in soils and fertilizers. These compounds are the real fertilizing substances and the other elements combined in them with the nitrogen, phosphorus and potassium are necessarily present in order that these three may be supplied to plants in a form that can be taken up and utilized. Examples may make this plainer.

Sodium nitrate or Chili saltpeter is one of the most valuable nitrogenous fertilizers. In the pure state it contains 16.5 per cent of nitrogen. It might seem that, if nitrogen is the element that it is desired to offer the crop, the remainder of the substance is "filler." This view would be quite wrong, however, as the sodium and the oxygen that make up the remaining 83.5 per cent are essential to the existance of the Chili saltpeter.

Similarly, potassium chloride, or "muriate of potash," another compound largely used in fertilizers, is only 52.3 per cent potassium, but the 47.7 per cent of chlorine present is as necessary to the formation of potassium chloride as is the potassium itself.

Again, if a superphosphate should be prepared from pure calcium phosphate and sulphuric acid it would contain only 12.2 per cent of phosphorus. It would also contain 23.7 per cent of calcium, which in some soils would be a valuable element to add. Even counting that, the sulphur, hydrogen and oxygen, constituting the remainder of the superphosphate and without which it could not exist, make up 64.1 per cent of the substance.

A fertilizer compounded of 1200 pounds of such pure superphosphate, 500 pounds of pure sodium nitrate and 300 pounds of pure potassium chloride per ton, would be a perfectly pure fertilizer, yet it would contain in the aggregate only 7.3 per cent of phosphorus, 7.8 of potassium and 4.1 of nitrogen, or 19.2 per cent all together. The remaining elements are unavoidably present, as plants cannot utilize the free elements, but must receive them in compounds such as those named.

It will be seen that even with perfectly pure fertilizing substances it is impossible to avoid a large percentage of seemingly useless elements. However, substances as they occur in nature are seldom pure, and the cost of purifying them is often very large. The phosphate rock of Florida, South Carolina and Tennessee is on the average much below pure calcium phosphate in its content of phosphorus, and to purify completely these natural products is not economically possible. It is much better to sell them in a somewhat impure condition, either with or without previous conversion into superphosphate, and pay freight on useless material, than to go to the great expense of putting the rock through a long and costly chemical process for its purification. Similar considerations apply to nitrogenous and potassic fertilizing materials also. One is, therefore, not in position to condemn a fertilizer as weighted with worse than useless "filler" until he knows what substances have been used as the source of the several elements of fertility and has made a somewhat troublesome arithmetical calculation.

It should also be clear that the valuation of any fertilizer can be made only by taking into consideration the percentage of the fertilizing elements, and that a guaranty concerning them is essential as a safeguard to the purchaser. It will also be seen that high-grade fertilizers are not only worth more because of their higher content of the fertilizing elements, but that pound for pound these elements are worth somewhat more in such fertilizers by reason of the saving in freight and handling.

EXPLANATION OF THE USE OF TABLE VIII.

Table VIII requires but little explanation. Although included here because of its applicability in making computations relative to fertilizers, it presents purely mathematical relations that may be used in connection with anything else. Really the figures in the columns headed "pounds required" are the reciprocals of numbers one one-hundredth as large as the numbers opposite under the heading "percentage present." Thus 1000 is the reciprocal of 0.001, 500 of 0.002, 125 of 0.008, 20 of 0.05, etc. This table has been made up by adapting and extending a table of reciprocals of numbers given in Holman's "Computation Rules and Logarithms."

Suppose that the farmer has decided to apply in a certain case 500 pounds of phosphorus to land, and to supply this in the form of a finely ground rock phosphate containing 13.5 per cent of phosphorus. By looking in table VIII, in the columns headed "percentage present," until the figures 13.5 are reached, one finds opposite, to the right, in the column headed "pounds required," the number 7.407. From this he knows that 7.407 pounds of the phosphate rock containing 13.5 per cent of phosphorus will furnish one pound of phosphorus; hence to get the 500 pounds of phosphorus required he must obtain 500 times 7.407, or 3703.5 pounds.

Suppose, on the other hand, that his data are stated in figures for "phosphoric acid" instead of phosphorus, and that he has decided to use 1145 pounds of "phosphoric acid" on his land, and that the rock phosphate that he has in view contains 30.9 per cent of "phosphoric acid." By finding in table VIII under "percentage present" the number 30.9, he finds opposite, to the right, under "pounds required," the number 3.236. This shows the number of pounds of the rock phosphate required to furnish one pound of phosphoric acid, and by multiplying 1145 by 3.236 he finds that 3705.2 pounds of the rock phosphate will be required. This result differs slightly from the one calculated from the figures for phosphorus, because in both cases small fractions have been dropped off.

Again, suppose that the farmer has decided to apply 500 pounds of phosphorus, but that in quoting prices to him the rock phosphate is guaranteed to contain 30.9 per cent of "phosphoric acid," how shall he proceed to ascertain the number of pounds necessary? He may find the amount of "phosphoric acid" equivalent to the 500 pounds of phosphorus by consulting table IX, thus finding it to be 1145 pounds. He will then continue as just described and compute the number of pounds of phosphate containing 30.9 per cent of "phosphoric acid" required to furnish 1145 pounds of "phosphoric acid." On the other hand, he may ascertain the percentage of phosphorus equivalent to 30.9 per cent of "phosphoric acid" by the use of table IX. This will be found to be 13.5, and the computation may be made as first described.

As already indicated, table VIII may be used for other purposes. If one knows the percentage of protein in a feed he can read off the number of pounds necessary to furnish one pound of protein. Thus if an alfalfa hay contains 12.3 per cent of protein, the table shows that 8.13 pounds of the hay will contain one pound of the protein.

If a lot of sugar beets contains 15.7 per cent of sugar the table shows that 6.369 pounds of the beets would contain a pound of sugar.

If corn silage contains 23 per cent of dry matter, 4.348 pounds would be required to furnish one pound of dry matter.

If an ore contains 11.2 per cent of copper, 8.929 pounds may be read directly from the table as the weight of ore that contains one pound of copper.

Examples might be multiplied indefinitely, but these will suffice to show the class of problems the solution of which is facilitated by table VIII.

TABLE VIII. Showing the number of pounds of a fertilizer required to furnish one pound of any element when the percentage of that element present in the fertilizer is known.

Percentage present....	Pounds required....	Percentage present....	Pounds required....	Percentage present....	Pounds required....	Precentage present....	Pounds required....
0.1	1000.00	6.4	15.63	12.7	7.874	19.0	5.263
0.2	500.00	6.5	15.38	12.8	7.813	19.1	5.236
0.3	333.33	6.6	15.15	12.9	7.752	19.2	5.208
0.4	250.00	6.7	14.93	13.0	7.692	19.3	5.181
0.5	200.00	6.8	14.71	13.1	7.634	19.4	5.155
0.6	166.67	6.9	14.49	13.2	7.576	19.5	5.128
0.7	142.86	7.0	14.29	13.3	7.512	19.6	5.102
0.8	125.00	7.1	14.08	13.4	7.463	19.7	5.076
0.9	111.11	7.2	13.89	13.5	7.407	19.8	5.051
1.0	100.00	7.3	13.70	13.6	7.353	19.9	5.025
1.1	90.91	7.4	13.51	13.7	7.299	20.0	5.000
1.2	83.33	7.5	13.33	13.8	7.246	20.1	4.975
1.3	76.92	7.6	13.16	13.9	7.194	20.2	4.950
1.4	71.43	7.7	12.99	14.0	7.143	20.3	4.926
1.5	66.63	7.8	12.82	14.1	7.092	20.4	4.902
1.6	62.50	7.9	12.66	14.2	7.042	20.5	4.878
1.7	58.82	8.0	12.50	14.3	6.993	20.6	4.854
1.8	55.56	8.1	12.35	14.4	6.944	20.7	4.831
1.9	52.63	8.2	12.20	14.5	6.897	20.8	4.808
2.0	50.00	8.3	12.05	14.6	6.849	20.9	4.785
2.1	47.62	8.4	11.90	14.7	6.803	21.0	4.762
2.2	45.45	8.5	11.76	14.8	6.757	21.1	4 739
2.3	43.48	8.6	11.63	14.9	6.711	21.2	4.717
2.4	41.67	8.7	11.49	15.0	6.667	21.3	4.695
2.5	40.00	8.8	11.36	15.1	6.623	21.4	4.673
2.6	38.46	8.9	11.24	15.2	6 579	21.5	4.651
2.7	37.04	9.0	11.11	15.3	6.536	21.6	4.630
2.8	35 71	9.1	10.99	15.4	6.494	21.7	4.608
2.9	34.48	9.2	10.87	15.5	6.452	21.8	4.587
3.0	33.33	9.3	10.75	15.6	6.410	21.9	4.566
3.1	32.26	9.4	10.64	15.7	6.369	22.0	4.545
3.2	31.25	9.5	10.53	15.8	6.329	22.1	4.525
3.3	30.30	9.6	10.42	15.9	6.289	22.2	4.505
3.4	29.41	9.7	10.31	16.0	6.250	22.3	4.484
3.5	28.57	9.8	10.20	16.1	6.211	22.4	4.464
3.6	27.78	9.9	10.10	16.2	6.173	22.5	4.444
3.7	27.03	10.0	10.00	16.3	6.135	22.6	4.425
3.8	26.32	10.1	9.901	16.4	6.098	22.7	4.405
3.9	25.64	10.2	9.804	16.5	6.061	22.8	4.386
4.0	25.00	10.3	9.709	16.6	6.024	22.9	4.367
4.1	24.39	10.4	9.615	16.7	5.988	23.0	4.348
4.2	23.81	10.5	9.524	16.8	5.952	23.1	4.329
4.3	23 26	10.6	9.434	16.9	5.917	23.2	4.310
4.4	22.73	10.7	9.346	17.0	5.882	23.3	4.292
4.5	22.22	10.8	9.259	17.1	5.848	23.4	4.274
4.6	21.74	10.9	9.174	17.2	5.814	23.5	4.255
4.7	21.28	11.0	9.091	17.3	5.780	23.6	4.237
4.8	20.83	11.1	9.009	17.4	5.747	23.7	4.219
4.9	20.41	11.2	8.929	17.5	5.714	23.8	4.202
5.0	20.00	11.3	8.850	17.6	5.682	23.9	4.184
5.1	19.61	11.4	8.772	17.7	5.650	24.0	4.167
5.2	19.23	11.5	8.696	17.8	5.618	24.1	4.149
5.3	18.87	11.6	8.621	17.9	5.587	24.2	4.132
5.4	18.52	11.7	8.547	18.0	5.556	24.3	4.115
5.5	18.18	11.8	8.475	18.1	5.525	24.4	4.098
5.6	17.86	11.9	8.403	18.2	5.495	24.5	4.082
5.7	17.54	12.0	8.333	18.3	5.464	24.6	4.065
5.8	17.24	12.1	8.264	18.4	5.435	24.7	4.049
5.9	16.95	12.2	8.197	18.5	5.405	24 8	4.032
6.0	16.67	12.3	8.130	18.6	5.376	24.9	4.016
6 1	16.39	12.4	8.065	18.7	5.348	25.0	4.000
6.2	16.13	12 5	8.000	18.8	5.319		
6.3	15.87	12.6	7.937	18.9	5.291		

TABLE VIII—*Continued.*

Percentage present...	Pounds required....	Percentage present...	Pounds required....	Percentage present...	Pounds required....	Percentage present...	Pounds required....
25.1	3.984	31.4	3.185	37.7	2.653	44.0	2.273
25.2	3.968	31.5	3.175	37.8	2.646	44.1	2.268
25.3	3.953	31.6	3.165	37.9	2.639	44.2	2.262
25.4	3.937	31.7	3.155	38.0	2.632	44.3	2.257
25.5	3.922	31.8	3.145	38.1	2.625	44.4	2.252
25.6	3.906	31.9	3.135	38.2	2.618	44.5	2.247
25.7	3.891	32.0	3.125	38.3	2.611	44.6	2.242
25.8	3.876	32.1	3.115	38.4	2.604	44 7	2.237
25.9	3.861	32.2	3.106	38.5	2.597	44.8	2.232
26.0	3.846	32.3	3.096	38.6	2.591	44.9	2.227
26.1	3.831	32.4	3.086	38.7	2.584	45.0	2.222
26.2	3.817	32.5	3.077	38.8	2.577	45.1	2.217
26.3	3.802	32.6	3.067	38.9	2.571	45.2	2.212
26.4	3.788	32.7	3.058	39.0	2.564	45.3	2.208
26.5	3.774	32.8	3.049	39.1	2.558	45.4	2.203
26.6	3.759	32.9	3.040	39.2	2.551	45.5	2.198
26.7	3.745	33.0	3.030	39.3	2.545	45.6	2.193
26.8	3.731	33.1	3.021	39.4	2.538	45.7	2.188
26.9	3.717	33.2	3.012	39.5	2.532	45.8	2.183
27.0	3.704	33.3	3.003	39.6	2.525	45.9	2.179
27.1	3.690	33.4	2.994	39 7	2.519	46.0	2.174
27.2	3.676	33.5	2.985	39.8	2.513	46.1	2.169
27.3	3.663	33.6	2.976	39.9	2.506	46.2	2.165
27.4	3.650	33.7	2.967	40.0	2.500	46.3	2.160
27.5	3.636	33.8	2.959	40.1	2.494	46.4	2 155
27.6	3.623	33.9	2.950	40.2	2.488	46.5	2.151
27.7	3.610	34.0	2.941	40.3	2.481	46.6	2.146
27.8	3.597	34.1	2.933	40.4	2.475	46.7	2.141
27.9	3.584	34.2	2.924	40.5	2.469	46.8	2.137
28.0	3.571	34.3	2.915	40.6	2.463	46 9	2.132
28.1	3.559	34.4	2.907	40.7	2.457	47.0	2.128
28.2	3.546	34.5	2.899	40.8	2.451	47.1	2.123
28.3	3.534	34.6	2.890	40.9	2.445	47.2	2.119
28.4	3.521	34.7	2.882	41.0	2.439	47.3	2.114
28.5	3.509	34.8	2.874	41.1	2.433	47.4	2.110
28.6	3.497	34.9	2.865	41.2	2.427	47.5	2.105
28.7	3.484	35.0	2.857	41.3	2.421	47.6	2.101
28.8	3.472	35.1	2.849	41.4	2.415	47.7	2.096
28.9	3.460	35.2	2.841	41.5	2.410	47.8	2.092
29.0	3.448	35.3	2.833	41.6	2.404	47.9	2.088
29.1	3.436	35.4	2.825	41.7	2.398	48.0	2.083
29.2	3.425	35.5	2.817	41.8	2.392	48.1	2.079
29.3	3.413	35.6	2.809	41.9	2.387	48.2	2.075
29.4	3.401	35.7	2.801	42.0	2.381	48.3	2.070
29.5	3.390	35.8	2.793	42.1	2.375	48.4	2.066
29.6	3.378	35.9	2.786	42.2	2.370	48.5	2.062
29.7	3.367	36.0	2.778	42.3	2.364	48.6	2.058
29.8	3.356	36.1	2.770	42.4	2.358	48.7	2.053
29.9	3.344	36.2	2.762	42.5	2.353	48.8	2.049
30.0	3.333	36.3	2.755	42.6	2.347	48.9	2.045
30.1	3.322	36.4	2.747	42.7	2.342	49.0	2.041
30.2	3.311	36.5	2.740	42.8	2.336	49.1	2.037
30.3	3.300	36.6	2.732	42.9	2.331	49.2	2.033
30.4	3.289	36.7	2.725	43.0	2.326	49.3	2.028
30.5	3.279	36.8	2 717	43.1	2 320	49.4	2.024
30.6	3.268	36.9	2.710	43.2	2.315	49.5	2.020
30.7	3.257	37.0	2.703	43.3	2.309	49.6	2.016
30.8	3.247	37.1	2.695	43.4	2.304	49.7	2.012
30.9	3.236	37.2	2.688	43.5	2.299	49.8	2.008
31.0	3.226	37.3	2.681	43.6	2.294	49.9	2.004
31.1	3.215	37.4	2.674	43.7	2.288	50.0	2.000
31.2	3.205	37.5	2.667	43.8	2.283		
31.3	3.195	37.6	2.660	43.9	2.278		

TABLE VIII—*Continued.*

Percentage present...	Pounds required....	Percentage present...	Pounds required....	Percentage present...	Pounds required....	Percentage present...	Pounds required....
50.1	1.996	56.4	1.773	62.7	1.595	69.0	1.449
50.2	1.992	56.5	1.770	62.8	1.592	69.1	1.447
50.3	1.988	56.6	1.767	62.9	1.590	69.2	1.445
50.4	1.984	56.7	1.764	63.0	1.587	69.3	1.443
50.5	1.980	56.8	1.761	63.1	1.585	69.4	1.441
50.6	1.976	56.9	1.757	63.2	1.582	69.5	1.439
50.7	1.972	57.0	1.754	63.3	1.580	69.6	1.437
50.8	1.969	57.1	1.751	63.4	1.577	69.7	1.435
50.9	1.965	57.2	1.748	63.5	1.575	69.8	1.433
51.0	1.961	57.3	1.745	63.6	1.572	69.9	1.431
51.1	1.957	57.4	1.742	63.7	1.570	70.0	1.429
51.2	1.953	57.5	1.739	63.8	1.567	70.1	1.427
51.3	1.949	57.6	1.736	63.9	1.565	70.2	1.425
51.4	1.946	57.7	1.733	64.0	1.563	70.3	1.422
51.5	1.942	57.8	1.730	64.1	1.560	70.4	1.420
51.6	1.938	57.9	1.727	64.2	1.558	70.5	1.418
51.7	1.934	58.0	1.724	64.3	1.555	70.6	1.416
51.8	1.931	58.1	1.721	64.4	1.553	70.7	1.414
51.9	1.927	58.2	1.718	64.5	1.550	70.8	1.412
52.0	1.923	58.3	1.715	64.6	1.548	70.9	1.410
52.1	1.919	58.4	1.712	64.7	1.546	71.0	1.408
52.2	1.916	58.5	1.709	64.8	1.543	71.1	1.406
52.3	1.912	58.6	1.706	64.9	1.541	71.2	1.404
52.4	1.908	58.7	1.704	65.0	1.538	71.3	1.403
52.5	1.905	58.8	1.701	65.1	1.536	71.4	1.401
52.6	1.901	58.9	1.698	65.2	1.534	71.5	1.399
52.7	1.898	59.0	1.695	65.3	1.531	71.6	1.397
52.8	1.894	59.1	1.692	65.4	1.529	71.7	1.395
52.9	1.890	59.2	1.689	65.5	1.527	71.8	1.393
53.0	1.887	59.3	1.686	65.6	1.524	71.9	1.391
53.1	1.883	59.4	1.684	65.7	1.522	72.0	1.389
53.2	1.880	59.5	1.681	65.8	1.520	72.1	1.387
53.3	1.876	59.6	1.678	65.9	1.517	72.2	1.385
53.4	1.873	59.7	1.675	66.0	1.515	72.3	1.383
53.5	1.869	59.8	1.672	66.1	1.513	72.4	1.381
53.6	1.866	59.9	1.669	66.2	1.511	72.5	1.379
53.7	1.862	60.0	1.667	66.3	1.508	72.6	1.377
53.8	1.859	60.1	1.664	66.4	1.506	72.7	1.376
53.9	1.855	60.2	1.661	66.5	1.504	72.8	1.374
54.0	1.852	60.3	1.658	66.6	1.502	72.9	1.372
54.1	1.848	60.4	1.656	66.7	1.499	73.0	1.370
54.2	1.845	60.5	1.653	66.8	1.497	73.1	1.368
54.3	1.842	60.6	1.650	66.9	1.495	73.2	1.366
54.4	1.838	60.7	1.647	67.0	1.493	73.3	1.364
54.5	1.835	60.8	1.645	67.1	1.490	73.4	1.362
54.6	1.832	60.9	1.642	67.2	1.488	73.5	1.361
54.7	1.828	61.0	1.639	67.3	1.486	73.6	1.359
54.8	1.825	61.1	1.637	67.4	1.484	73.7	1.357
54.9	1.821	61.2	1.634	67.5	1.481	73.8	1.355
55.0	1.818	61.3	1.631	67.6	1.479	73.9	1.353
55.1	1.815	61.4	1.629	67.7	1.477	74.0	1.351
55.2	1.812	61.5	1.626	67.8	1.475	74.1	1.350
55.3	1.808	61.6	1.623	67.9	1.473	74.2	1.348
55.4	1.805	61.7	1.621	68.0	1.471	74.3	1.346
55.5	1.802	61.8	1 618	68.1	1.468	74.4	1.344
55.6	1.799	61.9	1.616	68.2	1.466	74.5	1.342
55.7	1.795	62.0	1.613	68.3	1.464	74.6	1.340
55.8	1.792	62.1	1.610	68.4	1.462	74.7	1.339
55.9	1.789	62.2	1.608	68.5	1.460	74.8	1.337
56 0	1.786	62.3	1.605	68.6	1.458	74.9	1.335
56.1	1.783	62.4	1.603	68.7	1.456	75.0	1.333
56.2	1.779	62.5	1.600	68.8	1.453		
56.3	1.776	62.6	1.597	68.9	1.451		

TABLE VIII—*Concluded.*

Percentage present . . .	Pounds required	Percentage present . . .	Pounds required	Percentage present . . .	Pounds required	Percentage present . . .	Pounds required . . . .
75.1	1.332	81.4	1.229	87.7	1.140	94.0	1.064
75.2	1.330	81.5	1.227	87.8	1.139	94.1	1.063
75.3	1.328	81.6	1.225	87.9	1.138	94.2	1.062
75.4	1.326	81.7	1.224	88.0	1.136	94.3	1.060
75.5	1.325	81.8	1.222	88.1	1.135	94.4	1.059
75.6	1.323	81.9	1.221	88.2	1.134	94.5	1.058
75.7	1.321	82.0	1.220	88.3	1.133	94.6	1.057
75.8	1.319	82.1	1.218	88.4	1.131	94.7	1.056
75.9	1.318	82.2	1.217	88.5	1.130	94.8	1.055
76.0	1.316	82.3	1.215	88.6	1.129	94.9	1.054
76.1	1.314	82.4	1.214	88.7	1.127	95.0	1.053
76.2	1.312	82.5	1.212	88.8	1.126	95.1	1.052
76.3	1.311	82.6	1.211	88.9	1.125	95.2	1.050
76.4	1.309	82.7	1.209	89.0	1.124	95.3	1.049
76.5	1.307	82.8	1.208	89.1	1.122	95.4	1.048
76.6	1.305	82.9	1.206	89.2	1.121	95.5	1.047
76.7	1.304	83.0	1.205	89.3	1.120	95.6	1.046
76.8	1.302	83 1	1.203	89.4	1.119	95.7	1.045
76.9	1.300	83.2	1.202	89.5	1.117	95.8	1.044
77.0	1.299	83.3	1.200	89.6	1.116	95.9	1.043
77.1	1.297	83.4	1.199	89.7	1.115	96.0	1.042
77.2	1.295	83.5	1.198	89.8	1.114	96.1	1.041
77.3	1.294	83.6	1.196	89.9	1.112	96.2	1.040
77.4	1.292	83.7	1.195	90.0	1.111	96.3	1.038
77.5	1.290	83.8	1.193	90.1	1.110	96.4	1.037
77.6	1.289	83.9	1.192	90.2	1.109	96.5	1.036
77.7	1.287	84.0	1.190	90.3	1.107	96.6	1.035
77.8	1.285	84.1	1.189	90.4	1.106	96.7	1.034
77.9	1.284	84.2	1.188	90.5	1.105	96.8	1.033
78.0	1.282	84.3	1.186	90.6	1.104	96.9	1.032
78.1	1.280	84.4	1.185	90.7	1.103	97.0	1.031
78.2	1.279	84.5	1.183	90.8	1.101	97.1	1.030
78.3	1.277	84.6	1.182	90.9	1.100	97.2	1.029
78.4	1.276	84.7	1.181	91.0	1.099	97.3	1.028
78.5	1.274	84.8	1.179	91.1	1.098	97.4	1.027
78.6	1.272	84.9	1.178	91.2	1.096	97.5	1.026
78.7	1.271	85.0	1.176	91.3	1.095	97.6	1.025
78.8	1.269	85.1	1.175	91.4	1.094	97.7	1.024
78.9	1.267	85.2	1.174	91.5	1.093	97.8	1.022
79.0	1.266	85.3	1.172	91.6	1.092	97.9	1.021
79.1	1.264	85.4	1.171	91.7	1.091	98.0	1.020
79.2	1.263	85.5	1.170	91.8	1.089	98.1	1.019
79.3	1.261	85.6	1.168	91.9	1.088	98.2	1.018
79.4	1.259	85.7	1.167	92.0	1.087	98.3	1.017
79.5	1.258	85.8	1.166	92.1	1.086	98.4	1.016
79.6	1.256	85.9	1.164	92.2	1.085	98.5	1.015
79.7	1.255	86.0	1.163	92.3	1.083	98.6	1.014
79.8	1.253	86.1	1.161	92.4	1.082	98.7	1.013
79.9	1.252	86.2	1.160	92.5	1.081	98.8	1.012
80.0	1.250	86.3	1.159	92.6	1.080	98.9	1.011
80.1	1.248	86.4	1.157	92.7	1.079	99.0	1.010
80.2	1.247	86.5	1.156	92.8	1.078	99.1	1.009
80.3	1.245	86.6	1.155	92.9	1.076	99.2	1.008
80.4	1.244	86.7	1.153	93.0	1.075	99.3	1.007
80.5	1.242	86.8	1.152	93.1	1.074	99.4	1.006
80.6	1.241	86.9	1.151	93.2	1.073	99.5	1.005
80.7	1.239	87.0	1.149	93.3	1.072	99.6	1.004
80.8	1.238	87.1	1.148	93.4	1.071	99.7	1.003
80.9	1.236	87.2	1.147	93.5	1.070	99.8	1.002
81.0	1.235	87.3	1.145	93.6	1.068	99.9	1.001
81.1	1.233	87.4	1.144	93.7	1.067	100.0	1.000
81.2	1.232	87.5	1.143	93.8	1.066		
81.3	1.230	87.6	1.142	93.9	1.065		

EXPLANATION OF THE USE OF TABLES IX TO XII.

Tables IX to XII have been prepared for the purpose of facilitating the calculation of data stated in the old system into those of the element system, and those of the element system into the old. Each table is double, and gives for each whole number from 1 to 100 of the one substance the equivalent amount of the corresponding other substance. Figures are also given for each of the hundreds from 100 to 1000 for each substance. These tables have been calculated by machine, using the international atomic weights for 1910, and are believed to be absolutely accurate. These atomic weights are: Oxygen, 16; hydrogen, 1.008; nitrogen, 14.01; phosphorus, 31.00; potassium, 39.10; calcium, 40.09. They lead to the following factors for making calculations, and from which the tables were computed:

To compute "phosphoric acid" from phosphorus, multiply by 2.29032.

To compute phosphorus from "phosphoric acid," multiply by 0.43662.

To compute "potash" from potassium, multiply by 1.20460.

To compute potassium from "potash," multiply by 0.830149.

To compute ammonia from nitrogen, multiply by 1.21584.

To compute nitrogen from ammonia, multiply by 0.822472.

To compute lime from calcium, multiply by 1.39910.

To compute calcium from lime, multiply by 0.71474.

All of the tables are used in the same manner and may be illustrated by examples concerning phosphorus and "phosphoric acid."

If a fertilizer is guaranteed to contain 25 per cent of "phosphoric acid," what is its percentage of phosphorus? Look in the columns headed "phosphoric acid" until the number 25 is found; the number opposite, to the left, 10.9156, gives the figures for phosphorus.

If advised to apply 67 pounds of phosphorus to a piece of land, to how much "phosphoric acid" is that equivalent? Look in the columns headed "phosphorus" and find 67; opposite, to the right, the number 153.4514 shows the pounds of "phosphoric acid" that contain 67 pounds of phosphorus.

When the quantities to be reduced are not exactly given in the tables some calculation is necessary. Suppose, for example, that one wished to know the percentage, or the amount, of "phosphoric acid" equivalent to 9.3 of phosphorus. The table does not, unless by chance, show the equivalents except for whole numbers, hence 9.3 is not found in the phosphorus column. However, the figures can be obtained by looking opposite 93, and dividing by 10 the number given there. In this way the "phosphoric acid" corresponding to 9.3 of phosphorus is found to be, in round numbers, 21.3.

Further, suppose one desires to compute the phosphorus in 950 pounds of "phosphoric acid"; 950 is not found in the "phosphoric acid" column, but the desired figures may be found opposite 95, and by moving the decimal point to the right one place, to multiply by 10, we get 414.48 as the amount of phosphorus in 950 of "phosphoric acid."

Again, if it is desired to know the phosphorus equivalent to 756 pounds of "phosphoric acid," one looks in the columns headed "phosphoric acid," and obtains the figures for 700 pounds and 56 pounds separately. These are 305.63 and 24.45. Adding these together, 330.08 is obtained as the amount of phosphorus in 756 of "phosphoric acid."

Once more, if the percentage of "phosphoric acid" in a fertilizer is stated as 23.87, the percentage of phosphorus is found by looking in the table in the "phosphoric acid" columns and getting the phosphorus figures opposite 23 and 87 separately. Those for 87 are then divided by 100 by moving the decimal point two places to the left, thus getting the figures for .87. These are then added to those for 27. Thus, 10.04 + .38 = 10.42, the percentage of phosphorus in a fertilizer containing 23.87 per cent of "phosphoric acid."

These examples should suffice to show the method of using the table for phosphorus and "phosphoric acid," and precisely the same principles are used with tables X, XI and XII.

TABLE IX. Showing relation between phosphorus and "phosphoric acid" for certain amounts containing equal quantities of phosphorus.

Phosphorus. P	"Phosphoric acid." P_2O_5	Phosphorus. P	"Phosphoric acid." P_2O_5	Phosphorus. P	"Phosphoric acid." P_2O_5	Phosphorus. P	"Phosphoric acid." P_2O_5
0.4366	1.0000	17.0282	39.0000	34.0000	77.8709	65.0000	148.8708
0.8732	2.0000	17.4648	40.0000	34.0564	78.0000	66.0000	151.1611
1.0000	2.2903	17.9014	41.0000	34.4930	79.0000	67.0000	153.4514
1.3099	3.0000	18.0000	41.2258	34.9296	80.0000	68.0000	155.7418
1.7465	4.0000	18.3380	42.0000	35.0000	80.1612	69.0000	158.0321
2.0000	4.5806	18.7747	43.0000	35.3662	81.0000	70.0000	160.3224
2.1831	5.0000	19.0000	43.5161	35.8028	82.0000	71.0000	162.6127
2.6197	6.0000	19.2113	44.0000	36.0000	82.4515	72.0000	164.9030
3.0000	6.8710	19.6479	45.0000	36.2395	83.0000	73.0000	167.1934
3.0563	7.0000	20.0000	45.8064	36.6761	84.0000	74.0000	169.4837
3.4930	8.0000	20.0845	46.0000	37.0000	84.7418	75.0000	171.7740
3.9296	9.0000	20.5211	47.0000	37.1127	85.0000	76.0000	174.0643
4.0000	9.1613	20.9578	48.0000	37.5493	86.0000	77.0000	176.3546
4.3662	10.0000	21.0000	48.0967	37.9859	87.0000	78.0000	178.6450
4.8028	11.0000	21.3944	49.0000	38.0000	87.0322	79.0000	180.9353
5.0000	11.4510	21.8310	50.0000	38.4226	88.0000	80.0000	183.2256
5.2394	12.0000	22.0000	50.3870	38.8592	89.0000	81.0000	185.5159
5.6761	13.0000	22.2676	51.0000	39.0000	89.3225	82.0000	187.8062
6.0000	13.7419	22.7042	52.0000	39.2958	90.0000	83.0000	190.0966
6.1127	14.0000	23.0000	52.6774	39.7324	91.0000	84.0000	192.3869
6.5493	15.0000	23.1409	53.0000	40.0000	91.6128	85.0000	194.6772
6.9859	16 0000	23.5775	54.0000	40.1690	92.0000	86.0000	196.9675
7.0000	16.0322	24.0000	54.9677	40.6057	93.0000	87.0000	199.2578
7.4225	17.0000	24 0141	55.0000	41.0000	93.9031	87.3240	200.0000
7.8592	18.0000	24.4507	56.0000	41.0423	94.0000	88.0000	201.5482
8.0000	18.3226	24.8873	57.0000	41.4789	95.0000	89.0000	203.8385
8.2958	19.0000	25.0000	57.2580	41.9155	96.0000	90.0000	206.1288
8.7324	20.0000	25.3240	58.0000	42.0000	96.1934	91.0000	208.4191
9.0000	20.6129	25.7606	59.0000	42.3521	97.0000	92.0000	210.7094
9.1690	21.0000	26.0000	59.5483	42.7888	98.0000	93.0000	212.9998
9.6056	22.0000	26.1972	60.0000	43.0000	98.4838	94.0000	215.2900
10.0000	22.9032	26.6338	61.0000	43.2254	99.0000	95.0000	217.5804
10.0423	23.0000	27.0000	61.8386	43.6620	100.0000	96.0000	219.8707
10.4789	24.0000	27.0704	62.0000	44.0000	100.7741	97.0000	222.1610
10.9156	25.0000	27.5071	63.0000	45.0000	103.0644	98.0000	224.4514
11.0000	25.1936	27.9437	64.0000	46.0000	105.3547	99.0000	226.7417
11.3521	26.0000	28.0000	64.1290	47.0000	107.6450	100.0000	229.0320
11.7887	27.0000	28.3803	65.0000	48.0000	109.9354	130.9860	300.0000
12.0000	27.4838	28.8169	66.0000	49.0000	112.2257	174.6480	400.0000
12.2254	28.0000	29.0000	66.4193	50.0000	114.5160	200.0000	458.0640
12.6620	29.0000	29.2535	67.0000	51.0000	116.8063	218.3100	500.0000
13.0000	29.7742	29.6902	68.0000	52.0000	119.0964	261.9720	600.0000
13.0986	30 0000	30.0000	68.7096	53.0000	121.3870	300.0000	687.0960
13.5352	31.0000	30.1268	69.0000	54.0000	123.6773	305.6340	700.0000
13.9718	32.0000	30.5634	70.0000	55.0000	125.9676	349.2960	800.0000
14.0000	32.0645	31.0000	71.0000	56.0000	128.2579	392.9580	900.0000
14.4085	33.0000	31.4366	72.0000	57.0000	130.5482	400.0000	916.1280
14.8451	34.0000	31.8733	73.0000	58.0000	132.8386	436.6200	1000.0000
15.0000	34.3548	32.0000	73.2902	59.0000	135.1259	500.0000	1145.1600
15.2817	35.0000	32.3099	74.0000	60.0000	137.4192	600.0000	1374.1920
15.7183	36.0000	32.7465	75.0000	61.0000	139.7100	700.0000	1603.2240
16.0000	36.6451	33.0000	75.5806	62.0000	141.9998	800.0000	1832.2560
16.1549	37.0000	33.1831	76.0000	63.0000	144.2902	900.0000	2061.2880
16.5916	38.0000	33.6197	77.0000	64.0000	146.5805	1000.0000	2290.3200
17.0000	38.9354						

TABLE X. Showing relations between potassium and "potash" for certain amounts containing equal quantities of potassium.

Potassium. K	"Potash." K_2O	Potassium. K	"Potash." K_2O	Potassium. K	"Potash." K_2O	Potassium. K	"Potash." K_2O
0.8301	1.0000	25.7346	31.0000	50.6391	61.0000	75.0000	90.3450
1.0000	1.2046	26.0000	31.3196	51.0000	61.4346	75.5436	91.0000
1.6603	2.0000	26.5648	32.0000	51.4692	62.0000	76.0000	91.5496
2.0000	2.4092	27,0000	32.5242	52.0000	62.6392	76.3737	92.0000
2.4904	3.0000	27.3949	33.0000	52.2994	63.0000	77.0000	92.7542
3.0000	3.6138	28.0000	33.7288	53.0000	63.8438	77.2039	93.0000
3.3206	4.0000	28.2251	34.0000	53.1295	64.0000	78.0000	93.9588
4.0000	4.8184	29.0000	34.9334	53.9597	65.0000	78.0340	94.0000
4.1507	5.0000	29.0552	35.0000	54.0000	65.0484	78.8642	95.0000
4.9809	6.0000	29.8854	36.0000	54.7898	66.0000	79.0000	95.1634
5.0000	6.0230	30.0000	36.1380	55.0000	66.2530	79.6943	96.0000
5.8110	7.0000	30.7155	37.0000	55.6200	67.0000	80.0000	96.3680
6.0000	7.2276	31.0000	37.3426	56.0000	67.4576	80.5245	97.0000
6.6412	8.0000	31.5457	38.0000	56.4501	68.0000	81.0000	97.5726
7.0000	8.4322	32.0000	38.5472	57.0000	68.6622	81.3546	98.0000
7.4713	9.0000	32.3758	39.0000	57.2803	69.0000	82.0000	98.7772
8.0000	9.6368	33.0000	39.7518	58.0000	69.8668	82.1848	99.0000
8.3015	10.0000	33.2060	40.0000	58.1104	70.0000	83.0000	99.9818
9.0000	10.8414	34.0000	40.9564	58.9406	71.0000	83.0149	100.0000
9.1316	11.0000	34.0361	41.0000	59.0000	71.0714	84.0000	101.1864
9.9618	12.0000	34.8663	42.0000	59.7707	72.0000	85.0000	102.3910
10.0000	12.0460	35.0000	42.1610	60.0000	72.2760	86.0000	103.5956
10.7920	13.0000	35.6964	43.0000	60.6009	73.0000	87.0000	104.8002
11.0000	13.2506	36.0000	43.3656	61.0000	73.4806	88.0000	106.0048
11.6221	14.0000	36.5266	44.0000	61.4310	74.0000	89.0000	107.2094
12.0000	14.4552	37.0000	44.5702	62.0000	74.6852	90.0000	108.4140
12.4525	15,0000	37.3567	45.0000	62.2612	75.0000	91.0000	109.6186
13.0000	15,6598	38.0000	45.7748	63.0000	75.8898	92.0000	110.8232
13.2824	16.0000	38.1869	46.0000	63.0913	76.0000	93.0000	112.0278
14.0000	16.8644	39.0000	46.9794	63.9215	77.0000	94.0000	113.2324
14.1125	17.0000	39.0170	47.0000	64.0000	77.0944	95.0000	114.4370
14.9427	18.0000	39.8472	48.0000	64.7516	78.0000	96.0000	115.6416
15.0000	18.0690	40.0000	48.1840	65.0000	78.2990	97.0000	116.8462
15.7728	19.0000	40.6773	49.0000	65.5818	79.0000	98.0000	118.0508
16.0000	19.2736	41.0000	49.3886	66.0000	79.5036	99.0000	119.2554
16.6030	20.0000	41.5075	50.0000	66.4119	80.0000	100.0000	120.4600
17.0000	20.4782	42.0000	50.5932	67.0000	80.7082	166.0298	200.0000
17.4331	21.0000	42.3376	51.0000	67.2421	81.0000	200.0000	240.9200
18.0000	21.6828	43.0000	51.7978	68.0000	81.9128	249.0447	300.0000
18.2633	22.0000	43.1677	52.0000	68.0722	82.0000	300.0000	361.3800
19.0000	22.8874	43.9979	53.0000	68.9024	83.0000	332.0596	400.0000
19.0934	23.0000	44.0000	53.0024	69.0000	83.1174	400.0000	481.0000
19.9236	24.0000	44.8280	54.0000	69.7325	84.0000	415.0745	500.0000
20.0000	24.0920	45.0000	54.2070	70.0000	84.3220	498.0894	600.0000
20.7537	25.0000	45.6582	55.0000	70.5627	85.0000	500.0000	602.3000
21.0000	25.2966	46.0000	55.4116	71.0000	85.5266	581.1043	700.0000
21.5839	26.0000	46.4888	56.0000	71.3928	86.0000	600.0000	722.7600
22.0000	26.5012	47.0000	56.6162	72.0000	86.7312	664.1192	800.0000
22.4140	27.0000	47.3185	57.0000	72.2230	87.0000	700.0000	843.2200
23.0000	27.7058	48.0000	57.8208	73.0000	87.9358	747.1341	900.0000
23.2442	28.0000	48.1486	58.0000	73.0531	88.0000	800.0000	963.6800
24.0000	28.9104	48.9788	59.0000	73.8833	89.0000	830.0000	1000.0000
24.0743	29.0000	49.0000	59.0254	74.0000	89.1404	900.0000	1084.1400
24.9045	30.0000	49.8089	60.0000	74.7134	90.0000	1000.0000	1204.6000
25.0000	30.1150	50.0000	60.2300				

TABLE XI. **Showing relation between nitrogen and ammonia for certain amounts containing equal quantities of nitrogen.**

Nitrogen. N	Ammonia. NH_3	Nitrogen. N	Ammonia. NH_3	Nitrogen. N	Ammonia. NH_3	Nitrogen. N	Ammonia. NH_3
0.8225	1.0000	25.4966	31.0000	50.1708	61.0000	74.8450	90.0000
1.0000	1.2158	26.0000	31.6118	50.9933	62.0000	75.0000	91.1880
1.6449	2.0000	26.3191	32.0000	51.0000	62.0078	75.6674	92.0000
2.0000	2.4317	27.0000	32.8277	51.8157	63.0000	76.0000	92.4033
2.4674	3.0000	27.1416	33.0000	52.0000	63.2237	76.4899	93.0000
3.0000	3.6475	27.9640	34.0000	52.6382	64.0000	77.0000	93.6197
3.2899	4.0000	28.0000	34.0435	53.0000	64.4395	77.3124	94.0000
4.0000	4.8634	28.7865	35.0000	53.4607	65.0000	78.0000	94.8355
4.1124	5.0000	29.0000	35.2594	54.0000	65.6534	78.1348	95.0000
4.9348	6.0000	29.6090	36.0000	54.2832	66.0000	78.9573	96.0000
5.0000	6.0792	30.0000	36.4752	55.0000	66.8712	79.0000	96.0514
5.7573	7.0000	30.4315	37.0000	55.1056	67.0000	79.7798	97.0000
6.0000	7.2950	31.0000	37.6910	55.9280	68.0000	80.0000	97.2672
6.5798	8.0000	31.2539	38.0000	56.0000	68.0870	80.6023	98.0000
7.0000	8.5109	32.0000	38.9069	56.7506	69.0000	81.0000	98.4830
7.4022	9.0000	32.0764	39.0000	57.0000	69.3029	81.4247	99.0000
8.0000	9.7267	32.8989	40.0000	57.5730	70.0000	82.0000	99.6989
8.2247	10.0000	33.0000	40.1227	58.0000	70.5187	82.2472	100.0000
9.0000	10.9426	33.7214	41.0000	58.3955	71.0000	83.0000	100.9147
9.0472	11.0000	34.0000	41.3386	59.0000	71.7346	84.0000	102.1306
9.8697	12.0000	34.5438	42.0000	59.2180	72.0000	85.0000	103.3464
10.0000	12.1584	35.0000	42.5544	60.0000	72.9504	86.0000	104.5622
10.6921	13.0000	35.3663	43.0000	60.0405	73.0000	87.0000	105.7781
11.0000	13.3742	36.0000	43.7702	60.8629	74.0000	88.0000	106.9939
11.5146	14.0000	36.1888	44.0000	61.0000	74.1662	89.0000	108.2098
12.0000	14.5900	37.0000	44.9861	61.6854	75.0000	90.0000	109.4256
12.3371	15.0000	37.0112	45.0000	62.0000	75.3821	91.0000	110.6414
13.0000	15.8059	37.8337	46.0000	62.5079	76.0000	92.0000	111.8573
13.1596	16.0000	38.0000	46.2019	63.0000	76.5979	93.0000	113.0731
13.9820	17.0000	38.6562	47.0000	63.3303	77.0000	94.0000	114.2890
14.0000	17.0218	39.0000	47.4178	64.0000	77.8138	95.0000	115.5048
14.8045	18.0000	39.4787	48.0000	64.1528	78.0000	96.0000	116.7206
15.0000	18.2376	40.0000	48.6336	64.9753	79.0000	97.0000	117.5365
15.6270	19.0000	40.3011	49.0000	65.0000	79.0296	98.0000	119.1523
16.0000	19.4534	41.0000	49.8494	65.7978	80.0000	99.0000	120.3682
16.4494	20.0000	41.1236	50.0000	66.0000	80.2454	100.0000	121.5840
17.0000	20.6693	41.9461	51.0000	66.6202	81.0000	164.4944	200.0000
17.2719	21.0000	42.0000	51.0653	67.0000	81.4613	200.0000	243.1680
18.0000	21.8851	42.7685	52.0000	67.4427	82.0000	246.7416	300.0000
18.0944	22.0000	43.0000	52.2811	68.0000	82.6771	300.0000	364.7520
18.9169	23.0000	43.5910	53.0000	68.2652	83.0000	328.9880	400.0000
19.0000	23.1010	44.0000	53.4970	69.0000	83.8930	400.0000	486.3360
19.7393	24.0000	44.4135	54.0000	69.0876	84.0000	411.2360	500.0000
20.0000	24.3168	45.0000	54.7128	69.9101	85.0000	493.4832	600.0000
20.5618	25.0000	45.2360	55.0000	70.0000	85.1088	500.0000	607.9200
21.0000	25.5326	46.0000	55.9286	70.7326	86.0000	575.7304	700.0000
21.3843	26.0000	46.0584	56.0000	71.0000	86.3246	600.0000	729.5040
22.0000	26.7485	46.8809	57.0000	71.5551	87.0000	657.9776	800.0000
22.2067	27.0000	47.0000	57.1445	72.0000	87.5405	700.0000	851.0880
23.0000	27.9643	47.7034	58.0000	72.3775	88.0000	740.2248	900.0000
23.0292	28.0000	48.0000	58.3603	73.0000	88.7563	800.0000	972.6720
23.8517	29.0000	48.5258	59.0000	73.2000	89.0000	822.4720	1000.0000
24.0000	29.1802	49.0000	59.5762	74.0000	89.9722	900.0000	1094.2560
24.6742	30.0000	49.3483	60.0000	74.0225	90.0000	1000.0000	1215.8400
25.0000	30.3960	50.0000	60.7920				

TABLE XII. Showing relation between calcium and lime for certain amounts containing equal quantities of calcium.

Calcium. Ca	Lime. CaO	Calcium Ca	Lime. CaO	Calcium. Ca	Lime. CaO	Calcium. Ca	Lime. CaO
0.7147	1.0000	23.5864	33.0000	46.4581	65.0000	69.3298	97.0000
1.0000	1.3991	24.0000	33.5784	47.0000	65.7577	70.0000	97.9370
1.4295	2.0000	24.3012	34.0000	47.1728	66.0000	70.0445	98.0000
2.0000	2.7982	25.0000	34.9775	47.8876	67.0000	70.7593	99.0000
2.1442	3.0000	25.0159	35.0000	48.0000	67.1568	71.0000	99.3361
2.8590	4.0000	25.7306	36.0000	48.6023	68.0000	71.4740	100.0000
3.0000	4.1973	26.0000	36.3766	49.0000	68.5559	72.0000	100.7352
3.5737	5.0000	26.4454	37.0000	49.3171	69.0000	73.0000	102.1343
4.0000	5.5964	27.0000	37.7757	50.0000	69.9550	74.0000	103.5334
4.2884	6.0000	27.1601	38.0000	50.0318	70.0000	75.0000	104.9325
5.0000	6.9955	27.8749	39.0000	50.7465	71.0000	76.0000	106.3316
5.0032	7.0000	28.0000	39.1748	51.0000	71.3541	77.0000	107.7307
5.7179	8.0000	28.5896	40.0000	51.4613	72.0000	78.0000	109.1298
6.0000	8.3946	29.0000	40.5739	52.0000	72.7532	79.0000	110.5289
6.4327	9.0000	29.3043	41.0000	52.1760	73.0000	80.0000	111.9280
7.0000	9.7937	30.0000	41.9730	52.8908	74.0000	81.0000	113.3271
7.1474	10.0000	30.0191	42.0000	53.0000	74.1523	82.0000	114.7262
7.8621	11.0000	30.7338	43.0000	53.6055	75.0000	83.0000	116.1253
8.0000	11.1928	31.0000	43.3721	54.0000	75.5514	84.0000	117.5244
8.5769	12.0000	31.4486	44.0000	54.3202	76.0000	85.0000	118.9235
9.0000	12.5919	32.0000	44.7712	55.0000	76.9505	86.0000	120.3226
9.2916	13.0000	32.1633	45.0000	55.0350	77.0000	87.0000	121.7217
10 0000	13.9910	32.8780	46.0000	55.7497	78.0000	88.0000	123.1208
10.0064	14.0000	33.0000	46.1703	56.0000	78.3496	89.0000	124.5199
10.7211	15.0000	33.5928	47.0000	56.4645	79.0000	90.0000	125.9190
11.0000	15.3901	34.0000	47.5694	57.0000	79.7487	91.0000	127.3181
11.4358	16.0000	34.3075	48.0000	57.1792	80.0000	92.0000	128.7172
12.0000	16.7892	35.0000	48.9685	57.8939	81.0000	93.0000	130.1163
12.1506	17.0000	35.0223	49.0000	58.0000	81.1478	94.0000	131.5154
12.8653	18.0000	35.7370	50.0000	58.6087	82.0000	95.0000	132.9145
13.0000	18.1883	36.0000	50.3676	59.0000	82.5469	96.0000	134.3136
13.5801	19,0000	36.4517	51.0000	59.3234	83.0000	97.0000	135.7127
14.0000	19.5874	37.0000	51.7667	60.0000	83.9460	98.0000	137.1118
14.2948	20.0000	37.1665	52.0000	60.0382	84.0000	99.0000	138.5109
15.0000	20.9865	37.8812	53.0000	60.7529	85.0000	100.0000	139.9100
15.0085	21.0000	38.0000	53.1658	61.0000	85.3451	142.9480	200.0000
15.7243	22.0000	38.5960	54.0000	61.4676	86.0000	200.0000	279.8200
16.0000	22.3856	39.0000	54.5649	62.0000	86.7442	214.4220	300.0000
16.4390	23.0000	39.3107	55.0000	62.1824	87.0000	285.8960	400.0000
17.0000	23.7847	40.0000	55.9640	62.8971	88.0000	300.0000	419.7300
17.1538	24.0000	40.0254	56.0000	63.0000	88.1433	357.3700	500.0000
17.8685	25.0000	40.7402	57.0000	63.6119	89.0000	400.0000	559.6400
18.0000	25.1838	41.0000	57.3631	64.0000	89.5424	428.8440	600.0000
18.5832	26.0000	41.4549	58.0000	64.3266	90.0000	500.0000	699.5500
19.0000	26.5829	42.0000	58.7622	65.0000	90.4515	500.3180	700.0000
19.2980	27.0000	42.1697	59.0000	65.0413	91.0000	571.7920	800.0000
20.0000	27.9820	42.8844	69.0000	65.7561	92.0000	600.0000	839.4600
20.0127	28.0000	43.0000	60.1613	66.0000	92.3406	643.2660	900.0000
20.7275	29.0000	43.5991	61.0000	66.4708	93.0000	700.0000	979.3700
21.0000	29.3811	44.0000	61.5604	67.0000	93.7397	714.7400	1000.0000
21.4422	30.0000	44.3139	62.0000	67.1856	94.0000	800.0000	1119.2800
22.0000	30.7802	45.0000	62.9595	67.9003	95.0000	900.0000	1259.1900
22.1569	31.0000	45.0286	63.0000	68.0000	95.1388	1000.0000	1399.1000
22.8717	32.0000	45.7434	64.0000	68.6150	96.0000		
23.0000	32.1793	46.0000	64.3586	69.0000	96.5379		

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Circular No. 11....The Relation of Size, Weight and Density of Kernel to Germination of Wheat.

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Kansas State Agricultural College.

EXPERIMENT STATION.—Bulletin 170.

ED. H. WEBSTER, *Director*.

TECHNICAL BULLETIN.

Botanical Department.

H. F. ROBERTS, *Botanist in Charge*.

Breeding for Type of Kernel in Wheat.

BY

H. F. ROBERTS, *Botanist*.

MANHATTAN, KAN.
SEPTEMBER 19, 1910.
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Continued on 3d page of cover.

Breeding for Type of Kernel in Wheat, and Its Relation to the Grading and Milling of the Grain.

By H. F. Roberts.

Pure races of wheat, even of the same general type, show great diversities among themselves with respect to the form of the kernel. This is the case even among wheat races in which the kernel is in all instances hard and of high protein content. It therefore becomes necessary to distinguish, for breeding purposes, those races which show the most desirable types of kernel. In the improvement of the form of the wheat kernel two purposes have to be reckoned with:

First, the production of such a type of wheat berry as will mill to the greatest advantage—that is to say, which will yield a maximum amount of flour in proportion to the bran. It may be remarked that in the breeding of pure races of wheat—*i. e.*, "pure lines" in the sense used by Johannsen—we find great differences in the types of grain, even among the hard red winter wheats, with respect to this important matter of milling quality alone.

So far as the miller is concerned, there are certain well-defined preferences with respect to a desirable wheat for milling purposes. Leaving out the primary necessity, in our region at least, of a hard, semitranslucent wheat rich in gluten, and preferably a winter wheat of a dark reddish-amber color, we find that, so far as the form of the wheat kernel is concerned, the millers and grain dealers desire a full, plump berry in preference to a slender berry, on account of the relatively less amount of bran to the flour which such a kernel produces, and, for the same reason, a berry with a shallow crease is preferable to one with a deep crease. The deep crease is also an objectionable feature because of the considerable quantity of dirt that it holds, and which must be cleaned out in the scouring process as thoroughly as possible. Manifestly, a kernel with a deep crease will carry more dirt to the rolls than one with a shallow crease. A type of kernel devoid, so far as possible, of the mass of hairs surmounting the ovary, and called the "brush," is likewise desirable because of its lesser liability to carry dirt particles. So much for the preferred type of kernel for milling purposes. Following are illustrations of desirable and undesirable types of kernels. Plates I, II, III, IV and V.

Second, the breeder should endeavor to produce such a type of berry as will, by its superior packing quality in the grain tester, make a maximum weight in pounds to the bushel, and thus secure for the grain as sold a higher grading, and consequently a better price, than another type of berry equally good in other respects but testing at a lower pound rate per bushel.

The present investigation was directed, so far as the data to be herein presented are concerned, toward the relation of the form-factors of the wheat kernel to the volume-weight of the grain.

Wheat, before being sold, is "tested" by means of a standard "grain tester" in order to ascertain the number of pounds per bushel it will average. Upon this average bushel-weight and upon other considerations affecting the quality of the grain, as judged by its appearance, hardness, etc., the grain is "graded" according to a system of standards prescribed by the grain exchange or the state inspection department, as the case may be. The grade as thus fixed for any lot of wheat determines its market price. Wheat is, to be sure, sold entirely by weight in our market; but if, say, two lots of hard winter wheat weigh 1000 pounds each, and if one tests at 56 and the other at 62 pounds to the bushel, the latter will, other things being equal, go into a higher grade and bring a better price than the other.

Under the grading system of the Kansas and of the Minnesota State Grain Inspection Departments, for example, No. 1 Hard winter wheat must weigh not less than 61 pounds to the bushel, while No. 3 must weigh not less than 56 pounds. This weight requirement alone would finally determine the classification, although, of course, other factors of quality almost invariably accompany such differences in weight. Our experiments show that this is not necessarily the case, and that wheats equally good in all other respects may, on account of the form-factors of the kernel, give widely different test weights. Assuming two lots of wheat, testing at 62 pounds and 56 pounds, respectively, and grading No. 1 Hard and No. 3 Hard, the average spread between the prices of these two grades would run from about three cents on the bushel for

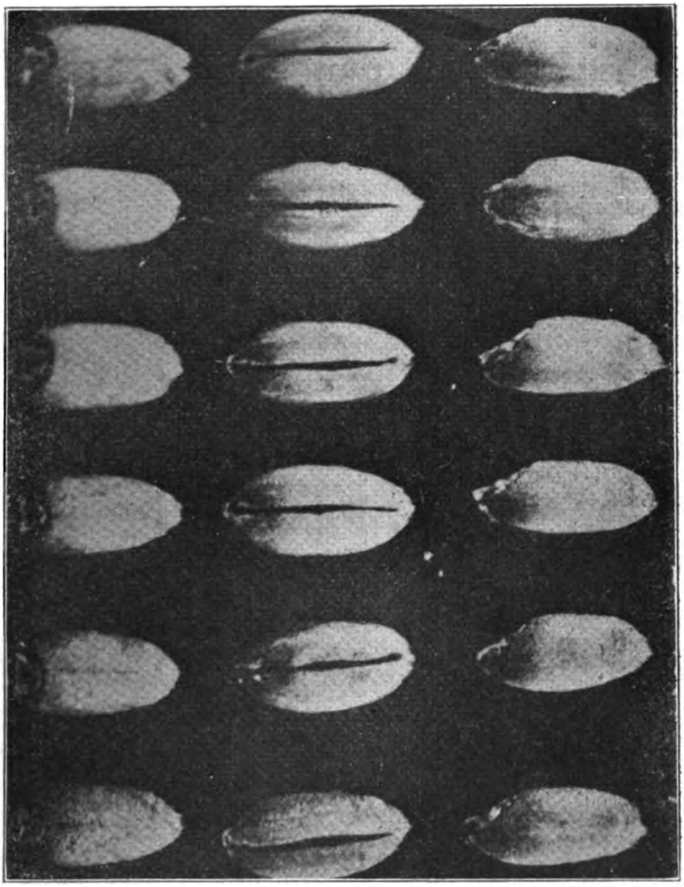

PLATE I. Pedigree No. 1064 × 3 dia.

Superior type of the wheat kernel to breed for: Pure-bred varieties having kernels of the type of this and of No. 1066 have been produced by breeding.

good years when the grades crowd closely together, to about five cents in bad years, when the differences between the upper and lower grades become more sharply marked. In the case supposed, the difference possible to be arrived at in the grading, due to differences in the test weight per bushel, would involve differences in market value of from thirty to fifty dollars on each 1000-bushel lot. It is possible, as will be demonstrated, to secure for wheat a considerably higher test reading by attention to the breeding of a type of kernel that will have superior packing qualities; along with which fact it is also the case that a superior type of kernel as regards shape for milling purposes is simultaneously secured. There is no question that

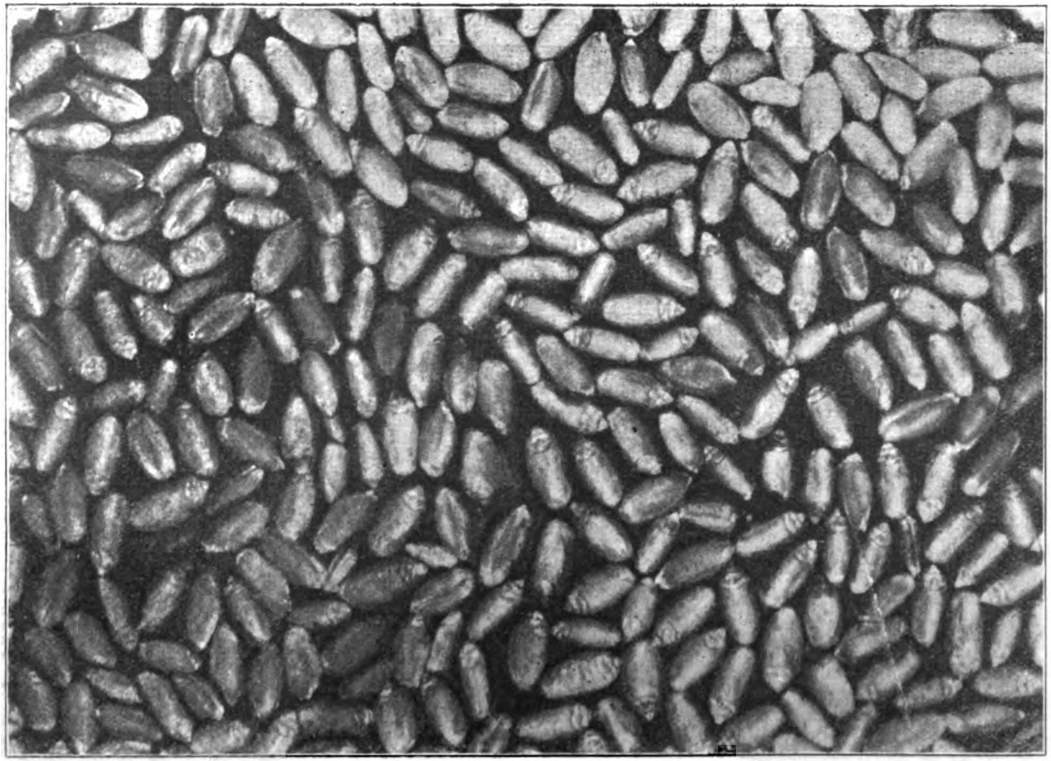

Plate II. Pedigree No. 1066 × 1⅛ dia.

One of the most desirable types of the wheat kernel. The grain rather short, thick, blunt at both ends; full, with a very shallow crease. Wheat having this type of kernel will mill to the greatest advantage, yielding a minimum amount of bran.

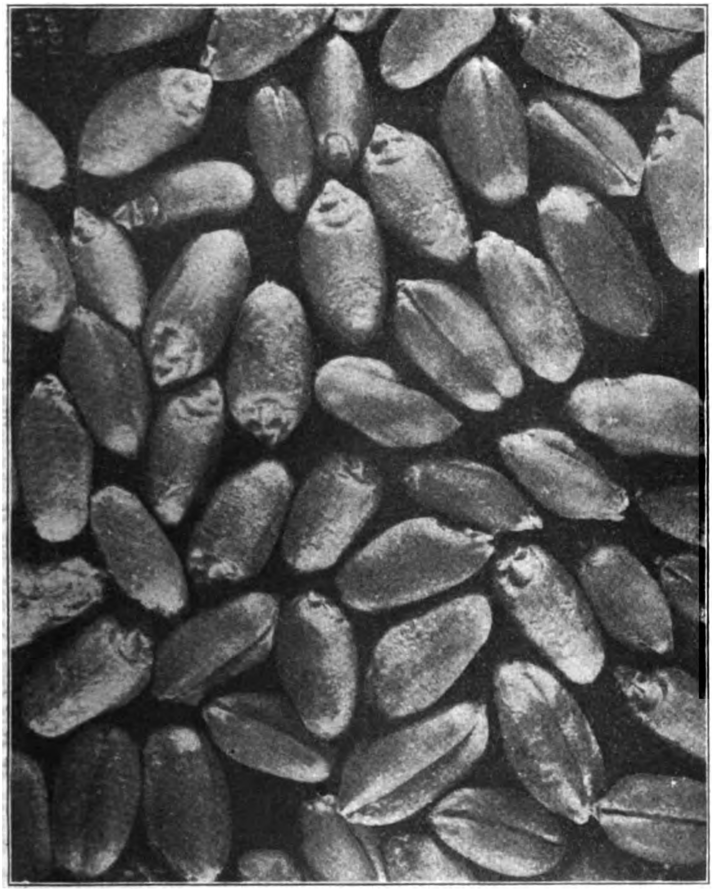

PLATE III. Pedigree No. 1066 × 3 dia.

Showing details of type of kernel characteristic of this variety—a hard red winter wheat of superior type.

the breeding of a specific type of kernel in wheat is, for these two reasons alone, of equal importance with that of the breeding of a specific type of kernel in corn; which latter has long since been recognized and settled upon. The relative smallness of the wheat kernel has obscured the fact of the importance of the form-factors in this grain, and no quantitative investigations along just these lines seem to have been undertaken hitherto.

What factors determine the differences in volume-weight which thus affect the grade and the market price of wheat? On first consideration, it would naturally be assumed that the

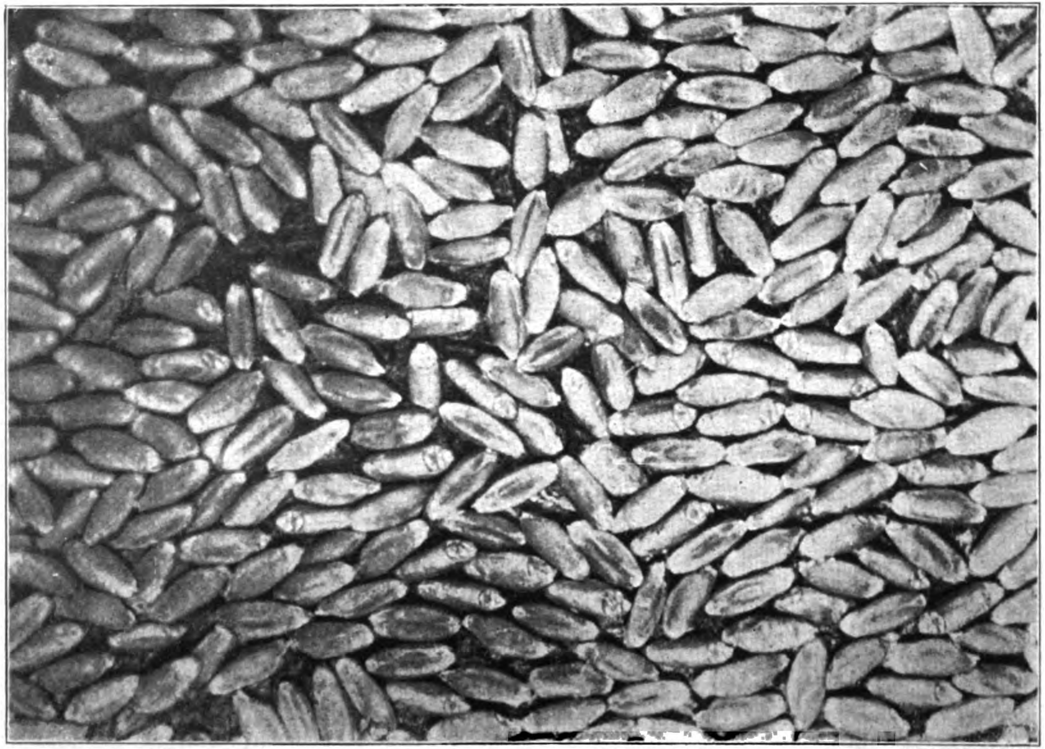

PLATE IV. Pedigree No. 722 × 1½ dia.

An inferior and undesirable type of kernel in wheat; the grain long, narrow, tapering, with a very deep crease. The crease of this type is not due to shrivelling, but is characteristic of certain types of wheat.

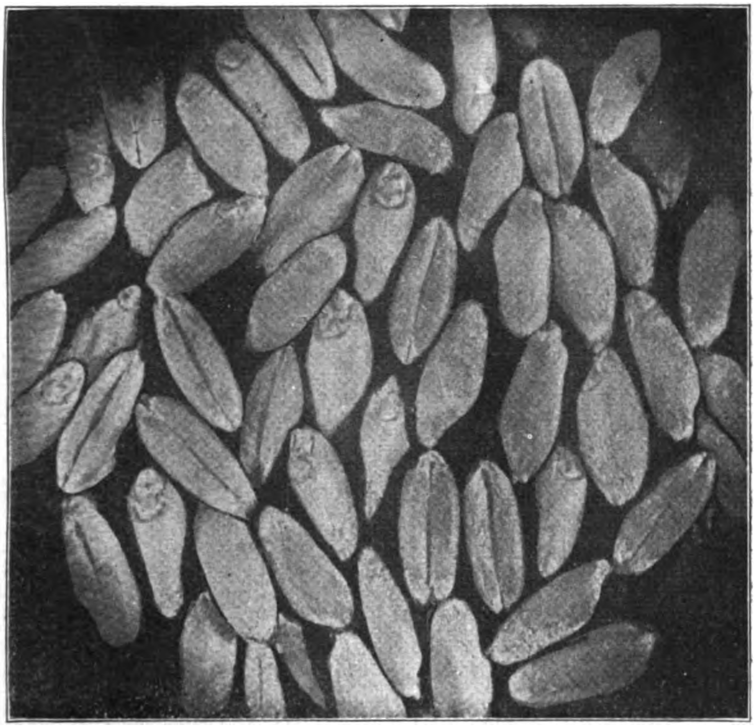

PLATE V. Pedigree No. 722 × 3 dia.
A bad type of milling wheat; kernel long, narrow, with deep crease, producing a maximum of bran.

specific gravity of the kernels would be the most important factor.

However, it was noticed that, among several hundred pure races ("pure lines") of wheat harvested in 1908 at the Kansas Experiment Station, in the breeding grounds of the department of botany, certain distinctive types of kernel existed, which seemed to pack more closely into a given volume than did others, and an investigation was instituted to determine the optimum type of wheat kernel in this regard.

It is sufficiently evident that, in the filling of any physical measure of volume, the number of units that can be gotten into it depends considerably upon their geometrical form, in cases where the volume of the individual kernels is identical; that is to say, for example, whether they are approximately spherical, egg-shaped, oblong, or the like.

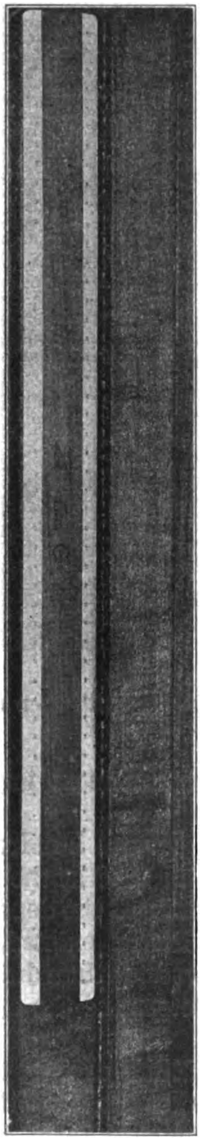

PLATE VI. **Measuring board for determining average lengths of kernels.**

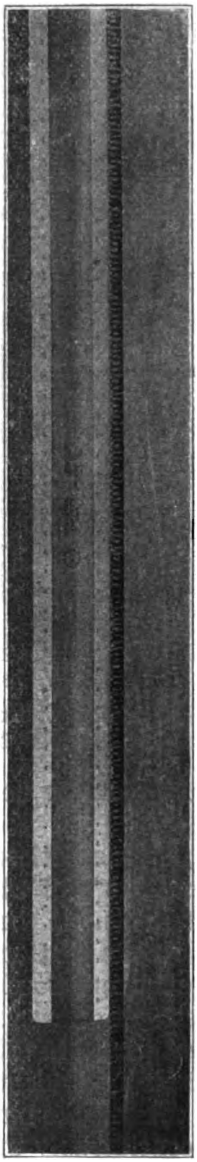

PLATE VII. **Measuring board for determining average widths of kernels.**

Manifestly, the bushel-weight is the sum of the weights of all the 900,000 to 1,400,000 individual kernels contained in it, and therefore the purpose of the wheat breeder in aiming to influence the bushel-weight for the benefit of the grower should be to select for breeding that race of wheat adapted to his region, which, in addition to having the highest average kernel-weight, also possesses a type of kernel that will admit of the greatest possible number of grains in a bushel measure.

In order to arrive at an unprejudiced judgment in the matter of the particular type of kernel to breed for, an investigation was conducted as follows:

Fifty-two pure races of wheat, showing amongst themselves a great diversity of types of kernel in respect to apparent length, width, contour and volume of the individual grains, and all of which had been growing for two successive years in our breeding grounds, were chosen for experiment, without regard to the economic value of the types of wheat selected.

Kernels of each of these races were subjected to a series of measurements in the following manner:

The average *length* of the kernels of each race was determined by taking, by random sampling, five lots of kernels, amounting by estimate to above 100 grains each, and from which in succession, and without choice, 100 kernels were taken and measured, by laying them end to end upon a measuring board designed by the writer (plate VI), making the number to be measured up to 100 by additional random samplings where necessary. The total length of such 100 kernels in millimeters, divided by the number of individual grains, gave an average that ran exceedingly close for each of the five samples of 100 chosen throughout the fifty-two different races. The total average length for each 500 kernels was therefore taken as the average or mean kernel-length of the race for the given season and locality.

Reference to the following table will indicate how accurate these averages are:

TABLE I.

No.	No. grains.	Av. length (mm.).........	Av. width (mm.).........	Ratio length to width.....	Av. volume (cu. mm.)....	Av. weight (g.)...........	Av. specific gravity.......	Av. volume-weight.			Packing quality.	
								Grams per 100 cc..	Lbs. per (packed) bushel.........	Lbs. per (struck) bushel.........	Per cent vol. in 100 cc. not occupied by grain...	Per cent vol. of grain in 100 cc..
418-8	1st 100	5.05	2.66	1.90	16.1	0.021	1.298					
	2d 100	5.03	2.59	1 94	16.0	.020	1.305					
	3d 100	5.15	2.67	1.93	16.5	.021	1.335					
	4th 100	5.16	2.64	1.95	15.5	.020	1.301					
	5th 100	5.16	2.70	1.91	16.0	.021	1.305					
Av.....	500	5.11	2.65	1.92	16.0	0.021	1.309	84.99	66.03	62.26	34.64	65.36
748	1st 100	6.19	2.50	2.47	18.0	0.025	1.358					
	2d 100	6.12	2.50	2.44	17.5	.024	1.386					
	3d 100	6.05	2.44	2.47	17.0	.023	1.377					
	4th 100	6.12	2.45	2.50	17.0	.023	1.375					
	5th 100	6.11	2.45	2.49	17.0	.023	1.371					
Av.....	500	6.12	2.47	2.47	17.3	0.024	1.373	83.77	65.08	58.11	37.60	62.40
778	1st 100	6.20	2.79	2.23	17.5	0.024	1.351					
	2d 100	6.00	2.80	2.14	17.5	.023	1.369					
	3d 100	6.20	2.76	2.24	17.0	.022	1.371					
	4th 100	5.90	2.75	2.14	16.5	.022	1.345					
	5th 100	5.50	2.76	2.00	16.5	.023	1.348					
Av.....	500	5.96	2.77	2.15	17.0	0.023	1 356	86.17	66.94	60.77	37.13	62.87
800	1st 100	5.82	2.78	2.09	18.0	0.025	1.355					
	2d 100	5.82	2.26	2.10	19.0	.025	1.348					
	3d 100	5.79	2.76	2.10	19.3	.025	1.350					
	4th 100	5.80	2.74	2.12	18.0	.025	1.353					
	5th 100	5.78	2.75	2.10	18.5	.025	1.355					
Av.....	500	5 80	2.76	2.10	18.6	0.025	1.352	86.08	66.87	62.75	36.60	63.40
819	1st 100	6.16	2.79	2.20	19.0	0.026	1.322					
	2d 100	6.16	2.76	2.23	19.5	.026	1.315					
	3d 100	6.19	2.76	2.24	20 0	.026	1.311					
	4th 100	6.18	2.79	2.21	20.5	.027	1.314					
	5th 100	6.21	2.81	2.21	20.5	.028	1.310					
Av.....	500	6.18	2.78	2.22	19.9	0.027	1.314	83.53	64.89	59.48	36.52	63.48
854	1st 100	6.06	2.93	2.06	21.5	0.028	1.334					
	2d 100	6.07	2.89	2.10	21.0	.028	1.341					
	3d 100	6.05	2.88	2.10	20.5	.028	1.341					
	4th 100	6.10	2.88	2.11	20.5	.028	1.330					
	5th 100	6.09	2.89	2.10	21.0	.029	1.332					
Av.....	500	6.07	2.89	2.10	20.9	0.028	1.336	83.70	65.02	59.21	37.47	62.53
860	1st 100	5.95	2.56	2.32	16.7	0.022	1.227					
	2d 100	5.88	2.59	2.27	16.5	.023	1.323					
	3d 100	5.90	2.59	2.27	16.0	.022	1.313					
	4th 100	5.89	2.60	2.26	17.0	.022	1.319					
	5th 100	5.88	2.57	2.28	16.0	.022	1.321					
Av.....	500	5 90	2 58	2.28	16.4	0.022	1.301	83 89	65.17	59.69	36.51	63.49
861	1st 100	5.96	2.68	2.22	18.5	0.025	1.338					
	2d 100	5.93	2.68	2.21	18.5	.025	1.345					
	3d 100	5.91	2.68	2 24	17.5	.024	1.341					
	4th 100	5.90	2.65	2.22	18.5	.024	1.336					
	5th 100	5.91	2.61	2.26	17.5	.024	1.336					
Av.....	500	5.92	2 65	2.23	18.1	0.024	1.339	84.16	65.38	59.16	37 17	62.83

TABLE I—*Continued.*

No.	No. grains.		Av. length (mm.)........	Av. width (mm.)........	Ratio length to width....	Av. volume (cu. mm.)....	Av. weight (g.)...........	Av. specific gravity........	Av. volume-weight.			Packing quality.	
									Grams per 100 cc..	Lbs. per (packed) bushel	Lbs. per (struck) bushel.........	Per cent vol. in 100 cc. not occupied by grain...	Per cent vol. of grain in 100 cc...
893	1st	100	6.26	2.68	2.33	20.0	0.026	1.264					
	2d	100	6.30	2.67	2.35	20.0	.027	1.258					
	3d	100	6.28	2.72	2.30	21.5	.028	1.270					
	4th	100	6.30	2.71	2.32	20 5	.027	1.273					
	5th	100	6.27	2.73	2.29	22.5	.028	1.271					
Av.....		500	6.28	2.70	2.32	20.9	0.027	1.267	83.01	64.49	59.33	35.85	64.15
907	1st	100	5.14	2.67	1.92	15.0	0.020	1.327					
	2d	100	5.14	2.64	1.94	14.5	.019	1.318					
	3d	100	5.14	2.75	1.86	15.5	.020	1.313					
	4th	100	5.11	2.69	1.90	15.0	.020	1.310					
	5th	100	5.10	2.68	1.90	15.0	.020	1.316					
Av.....		500	5.13	2 69	1.90	15 0	0.020	1 316	84.21	65.42	57.41	36.76	63.24
921	1st	100	5.69	2 74	2.07	17.0	0.024	1.306					
	2d	100	5.65	2.78	2.03	18.0	.024	1.315					
	3d	100	5.67	2.76	2.05	17 0	.023	1.297					
	4th	100	5.63	2.75	2.04	18.0	.023	1.304					
	5th	100	5.64	2.76	2.04	18.4	.024	1.322					
Av....		500	5.66	2.76	2.05	18.0	0.024	1.309	78.64	61.09	56.48	38.36	61.64
927	1st	100	6.13	2.88	2.12	21.5	0.029	1.325					
	2d	100	6.12	2.92	2.09	22.0	.030	1.330					
	3d	100	6.10	2.89	2.11	22.5	.029	1.322					
	4th	100	6.11	2.91	2.10	22.5	.031	1.324					
	5th	100	6.10	2.93	2.08	23.5	.030	1.332					
Av.....		500	6.11	2.91	2.10	22.4	0.030	1.325	85.41	66.35	60.31	35.48	64.52
932	1st	100	6.17	3.01	2.04	25.5	0.034	1.331					
	2d	100	6 17	3 02	2.04	24.5	.034	1.331					
	3d	100	6.18	3.01	2.05	24.5	.033	1.322					
	4th	100	6.19	3.00	2.06	24.5	.033	1.331					
	5th	100	6.21	3.02	2.05	25.5	.035	1.318					
Av...		500	6.18	3.01	2.05	24.9	0.034	1.337	88.77	68.96	64.07	34.52	65.48
935	1st	100	5.57	2.52	2.21	16.5	0.023	1.350					
	2d	100	5.60	2.51	2.23	16.5	.023	1.353					
	3d	100	5.61	2.56	2.19	16.0	.024	1.366					
	4th	100	5.59	2.54	2.20	17.5	.024	1.359					
	5th	100	5.58	2.56	2.17	17.0	.023	1.358					
Av.....		500	5.59	2.54	2.20	16.7	0.023	1.357	88.27	68.58	63.39	35.08	64.92
940	1st	100	6.33	2.37	2.67	26.5	0.037	1.329					
	2d	100	6.31	2.35	2.68	26.5	.037	1.331					
	3d	100	6.34	2.33	2.72	26.5	.037	1.326					
	4th	100	6.31	2.35	2.68	26.2	.037	1.324					
	5th	100	6.32	2.32	2.72	26.0	.036	1.302					
Av.....		500	6.32	2.34	2.70	26.3	0.037	1.322	88.88	69.05	63.23	35.17	64.83
951	1st	100	6.11	2.82	2.16	21.4	0.029	1.311					
	2d	100	6.10	2.78	2 19	20.5	.028	1.336					
	3d	100	6.09	2.78	2.19	21.0	.029	1.330					
	4th	100	6.06	2.78	2.18	20.2	.028	1.322					
	5th	100	6.05	2.78	2.17	22.0	.028	1.326					
Av.....		500	6.08	2.79	2.17	21.0	0.028	1.325	87.33	67.84	58.94	37.51	62.49

TABLE I—*Continued*.

No.	No. grains.		Av. length (mm.)........	Av. width (mm.)........	Ratio length to width....	Av. volume (cu. mm.)....	Av. weight (g.)..........	Av. specific gravity	Av. volume-weight.			Packing quality.	
									Grams per 100 cc...	Lbs. per (packed) bushel.........	Lbs per (struck) bushel.........	Per cent vol. in 100 cc. not occupied by grain...	Per cent vol. of grain in 100 cc..
983	1st	100	6.02	2.63	2.28	18.5	0.025	1.337					
	2d	100	5.96	2.62	2.27	18.0	.026	1.336					
	3d	100	5.94	2.57	2.31	17.5	.023	1.328					
	4th	100	5.97	2.63	2.27	18.0	.025	1.323					
	5th	100	5.94	2.56	2.32	17.5	.023	1.333					
Av.....		500	5.97	2.60	2.29	17.9	0.024	1.334	86.17	66.94	60.60	35.52	64.48
994	1st	100	5.83	2.86	2.03	21.0	0 028	1.278					
	2d	100	5.81	2.87	2.02	20.5	.027	1.290					
	3d	100	5.80	2.84	2.04	20.5	.027	1.313					
	4th	100	5.81	2.84	2.04	20.0	.026	1.289					
	5th	100	5.83	2.82	2.06	19.5	.026	1.289					
Av.....		500	5.82	2.85	2.04	20.3	0.027	1.292	83.18	63.84	58.06	36.66	63.34
1008	1st	100	5.97	2.91	2.05	21.5	0.024	1.351					
	2d	100	6.01	2.90	2.07	22.0	.024	1.335					
	3d	100	5.96	2.86	2.08	21.0	.024	1.350					
	4th	100	6.00	2.87	2.09	22.0	.024	1.350					
	5th	100	5.96	2.88	2.07	21.5	.025	1.352					
Av.....		500	5.98	2.88	2.07	21.6	0.024	1.349	86.06	66.86	61.86	36.20	63.80
1014	1st	100	5.89	2.74	2.15	19.0	0.025	1.284					
	2d	100	5.95	2.79	2.13	19.5	.025	1.283					
	3d	100	5.94	2.79	2.13	19.0	.025	1.276					
	4th	100	5.90	2.74	2.15	19.5	.025	1.278					
	5th	100	5.89	2.74	2.15	19.0	.024	1.270					
Av.....		500	5.91	2.76	2.14	19.2	0.025	1.278	79.27	61.58	55.50	37.88	62.12
1016	1st	100	5.91	2.82	2.09	20.5	0.028	1.355					
	2d	100	5.89	2.78	2.11	19.5	.027	1.356					
	3d	100	5.93	2.79	2.12	20.5	.028	1.346					
	4th	100	5.93	2.80	2.11	21.0	.028	1.333					
	5th	100	5.96	2.83	2.10	21.0	.029	1.338					
Av.....		500	5.92	2.80	2.11	20.5	0.028	1.345	80.78	62.76	56.48	37.94	62.06
1018	1st	100	5.77	2.72	2.12	18.5	0.025	1.331					
	2d	100	5.82	2.69	2.16	18.0	.025	1.33					
	3d	100	5.77	2.74	2.10	19.0	.026	1.346					
	4th	100	5.77	2.69	2.14	18.0	.025	1.332					
	5th	100	5.78	2.69	2.14	18.0	.025	1.332					
Av.....		500	5.78	2.71	2.13	18.3	0.025	1.335	85.41	66.85	60.63	36.64	63.36
1023	1st	100	6.70	2.33	2.87	18.0	0.024	1.315					
	2d	100	6.75	2.38	2.83	18.0	.026	1.319					
	3d	100	6.75	2.37	2.84	18.0	.025	1.319					
	4th	100	6.75	2.37	2.84	19.0	.025	1.321					
	5th	100	6.70	2.37	2.82	18.0	.025	1.329					
Av.....		500	6.73	2.36	2 84	18.0	0.025	1.321	79.04	61.49	53 37	41 09	58.91
1040	1st	100	6.89	2.91	2.36	26.5	0.035	1.298					
	2d	100	6.89	2.94	2.34	25.5	.036	1.306					
	3d	100	6.86	2.89	2.37	25.5	.033	1.302					
	4th	100	6.86	2 91	2.35	26.5	.034	1.297					
	5th	100	6.85	2.86	2.39	25.0	.033	1.296					
Av.....		500	6.87	2.90	2.36	25.8	0.034	1.300	80.53	65.18	54.78	39.60	60.40

TABLE I—*Continued.*

No.	No. grains.	Av. length (mm.)........	Av. width (mm.)........	Ratio length to width....	Av. volume (cu. mm.).....	Av. weight (g.)..........	Av. specific gravity.......	Av. volume-weight.			Packing quality.	
								Grams per 100 cc..	Lbs. per (packed) bushel.........	Lbs. per (struck) bushel.........	Per cent vol. in 100 cc. not occupied by grain...	Per cent vol. of grain in 100 cc..
1059-1	1st 100	5.78	2.63	2.19	17.5	0.024	1.302					
	2d 100	5.76	2.56	2.25	17.5	.023	1.298					
	3d 100	5.75	2.56	2.24	17.5	.023	1.296					
	4th 100	5.73	2.57	2.22	17.5	.023	1.302					
	5th 100	5.76	2.57	2.24	17.5	.023	1.296					
Av....	500	5.76	2.58	2.23	17.5	0.023	1.299	81.15	63.04	57.05	39.23	60.77
1064	1st 100	5.91	2.87	2.05	21.0	0.029	1.341					
	2d 100	5.94	2.85	2 08	21.4	.030	1.354					
	3d 100	5.97	2.85	2.09	21.0	.030	1.346					
	4th 100	5.97	2.84	2.10	20.0	.030	1.365					
	5th 100	5.91	2.83	2.08	21.0	.029	1.345					
Av....	500	5.94	2.85	2.08	20.9	0.030	1.350	83.00	68.37	62.05	36.67	63.33
1066	1st 100	5.97	2 98	2.03	23.0	0.032	1.328					
	2d 100	5.98	2.96	2.02	24.0	.033	1.334					
	3d 100	6.02	2.97	2.02	24.0	.033	1.335					
	4th 100	5.99	2.95	2.03	23.0	.032	1.337					
	5th 100	5.98	2.96	2.02	24.0	.032	1.338					
Av....	500	5.98	2.96	2.02	23.6	0.033	1.336	91.36	70.98	65.25	34.90	65.10
1069	1st 100	5.80	2.40	2.41	14.5	0.019	1.323					
	2d 100	5.77	2.42	2.38	15.0	.020	1 297					
	3d 100	5.74	2.43	2.36	14.5	.019	1.320					
	4th 100	5.74	2.43	2 36	16.0	.021	1.329					
	5th 100	5.75	2.43	2.36	15.0	.021	1.325					
Av....	500	5.76	2.42	2.38	15.0	0.020	1.320	80.86	62.82	58.82	38.08	61.92
1071	1st 100	5.50	2.36	2.33	13.5	0.018	1.277					
	2d 100	5.54	2.39	2.31	15.0	.019	1.281					
	3d 100	5.52	2.37	2.32	14.5	.019	1.285					
	4th 100	5.50	2.42	2 27	15.0	.020	1.276					
	5th 100	5.55	2.44	2 27	15.0	.021	1.286					
Av....	500	5.52	2.40	2.30	14.6	0.019	1.281	80.57	62.59	55.99	38.48	61.52
1074	1st 100	5.76	2.84	2.02	20.0	0.028	1.331					
	2d 100	5.73	2.82	2.03	20.0	.027	1.320					
	3d 100	5.76	2.84	2.02	21.0	.028	1.349					
	4th 100	5.78	2.86	2 02	21.0	.029	1.341					
	5th 100	5 73	2.82	2.03	20.0	.028	1.337					
Av....	500	5.75	2.84	2 02	20.0	0 028	1.336	83.59	68.82	62.31	35.84	64.16
1078	1st 100	6.42	2.77	2.31	22.0	0.029	1.304					
	2d 100	6.41	2.72	2.35	20.5	.028	1.307					
	3d 100	6 42	2.74	2.34	21.5	.029	1 310					
	4th 100	6.37	2.72	2.34	21.0	.028	1.292					
	5th 100	6.44	2.72	2.36	20.5	.028	1 300					
Av.	500	6.41	2 73	2 34	21.1	0 028	1.303	83.35	64.75	57.56	37 52	62.48
1080	st 100	6.10	2.60	2.34	19.0	0.025	1.345					
	2d 100	6.11	2.60	2.35	19.0	.026	1.339					
	3d 100	6.09	2.57	2 36	18.5	.025	1.340					
	4th 100	6.11	2 55	2.39	18.5	.025	1.344					
	5th 100	6.06	2.58	2.34	18.0	.025	1.338					
Av....	500	6.09	2.58	2 36	18.6	0.025	1.341	85.99	66.80	57.78	37.84	62.16

TABLE I—*Continued.*

No.	No. grains.	Av. length (mm.)	Av. width (mm.)	Ratio length to width	Av. volume (cu. mm.)	Av. weight (g.)	Av. specific gravity	Av. volume-weight.			Packing quality.	
								Grams per 100 cc.	Lbs. per (packed) bushel	Lbs. per (struck) bushel	Per cent vol. in 100 cc. not occupied by grain	Per cent vol. of grain in 100 cc.
1081	1st 100	6.01	2.69	2.23	20.5	0.026	1.350					
	2d 100	5.99	2.69	2.22	19.0	.026	1.353					
	3d 100	6 01	2.69	2.23	20.0	.027	1.352					
	4th 100	5.98	2.68	2.23	19.0	.026	1.351					
	5th 100	6.01	2.65	2.26	20.0	.026	1.344					
Av.…	500	6.00	2.68	2.23	19.7	0.026	1.350	86.82	67.06	62.55	37.94	62.06
1082-1	1st 100	5.96	2.43	2.45	16.5	0.022	1.326					
	2d 100	6.01	2.39	2.51	16.5	.021	1.320					
	3d 100	6.00	2.38	2.52	16.0	.021	1.322					
	4th 100	5 99	2.40	2 49	16.0	.021	1.324					
	5th 100	5.96	2.39	2.49	15.5	.021	1.323					
Av.…	500	5.98	2.40	2.49	16.1	0.021	1.323	82.99	64.47	57.76	38.64	61.36
1105	1st 100	6.47	2.87	2.25	24.5	0.034	1.305					
	2d 100	6.53	2.90	2.25	24.5	.034	1.302					
	3d 100	6.47	2.87	2.25	25.0	.033	1.304					
	4th 100	6.48	2.89	2.24	25.5	.034	1.307					
	5th 100	6.50	2.88	2.26	25.0	.034	1.303					
Av.…	500	6 49	2.88	2.25	24.9	0.034	1.304	87.62	68.07	63.21	34.12	65.88
1108	1st 100	6.32	2.50	2.52	18.0	0.024	1.330					
	2d 100	6.32	2.50	2.52	18.5	.024	1.329					
	3d 100	6.29	2.49	2.52	18.0	.024	1.322					
	4th 100	6.30	2.48	2.54	17.0	.024	1.328					
	5th 100	6.34	2.50	2.53	18.0	.025	1.315					
Av.…	500	6.31	2.49	2.52	17.0	0.024	1.325	83.31	63.95	57.73	38.30	61.70
1110	1st 100	5.97	2.79	2.04	20.0	0.026	1.308					
	2d 100	5.96	2.78	2.14	19.0	.026	1.310					
	3d 100	5.95	2.81	2.12	20.2	.028	1.309					
	4th 100	5.98	2.80	2.13	20.0	.028	1.315					
	5th 100	5.94	2.79	2.13	20.0	.026	1.308					
Av.…	500	5.96	2.79	2.13	19.8	0.027	1.309	83.66	64.99	59.30	37 23	62.77
1111	1st 100	5.78	3.06	1.88	23.0	0.032	1.301					
	2d 100	5.81	3.05	1.90	24.0	.032	1 295					
	3d 100	5.80	3.12	1.86	25.0	.034	1.295					
	4th 100	5.81	3.11	1.87	24.5	.033	1.300					
	5th 100	5.84	3.11	1.87	25.0	.033	1.297					
Av.…	500	5.81	3.09	1.88	24.3	0.033	1.298	86.81	67.44	62.47	34.68	65.32
1112	1st 100	6.15	2.85	2.15	23.0	0 032	1.337					
	2d 100	6.13	2.89	2.12	22.5	.032	1.345					
	3d 100	6.10	2.84	2.14	22.5	.030	1.360					
	4th 100	6.18	2.89	2.13	23.0	.032	1.347					
	5th 100	6.13	2.89	2.12	22.5	.032	1 340					
Av.…	500	6.14	2 87	2.13	22.7	0.032	1.346	88.64	68.87	62.84	35.76	64.24
1113	1st 100	6.11	2.89	2.11	21.0	0.029	1.345					
	2d 100	6.15	2.95	2.08	22.5	.030	1.334					
	3d 100	6.12	2.93	2.08	21.5	.030	1.326					
	4th 100	6.19	2.96	2.09	22 5	.031	1.334					
	5th 100	6.17	2.94	2.09	21.5	.030	1.327					
Av.…	500	6.15	2.93	2.09	21.8	0.030	1.333	85.93	66 76	61.22	36.87	63.13

TABLE I—*Continued.*

No.	No. grains.	Av. length (mm.)........	Av. width (mm.)........	Ratio length to width....	Av. volume (cu. mm.)....	Av. weight (g.)........	Av. specific gravity.......	Av. volume-weight.			Packing quality.	
								Grams per 100 cc..	Lbs. per (packed) bushel.........	Lbs. per (struck) bushel.........	Per cent vol. in 100 cc. not occupied by grain...	Per cent vol. of grain in 100 cc..
1114	1st 100	5.68	2.69	2.11	18.5	0.023	1.298					
	2d 100	5.70	2.70	2.11	19.1	.024	1.300					
	3d 100	5.68	2.67	2.12	17.5	.023	1.300					
	4th 100	5.71	2.70	2.11	18.4	.024	1.300					
	5th 100	5.67	2.70	2.10	17.7	.023	1.295					
Av.....	500	5.69	2.69	2.11	18.2	0.023	1.298	84.89	65.95	60.16	36.10	63.90
1115	1st 100	6.16	3.05	2 02	25.5	0.034	1.306					
	2d 100	6.19	3.05	2.03	25.0	.033	1.290					
	3d 100	6.22	3.06	2.03	25.0	.034	1.300					
	4th 100	6.16	3.03	2.03	25.5	.034	1.302					
	5th 100	6.24	3.04	2.05	25.5	.034	1.311					
Av.....	500	6.19	3.05	2.03	25 3	0.034	1.302	84.64	65.75	60.45	35.50	64.50
1116	1st 100	6.26	2.90	2.15	24.0	0.032	1 284					
	2d 100	6.21	2.91	2.13	24.0	.032	1.300					
	3d 100	6.22	2.90	2.14	24.5	.033	1.284					
	4th 100	6.25	2.90	2.15	24.5	.033	1.295					
	5th 100	6.22	2.88	2.16	26.0	.033	1.300					
Av.....	500	6.23	2.90	2.14	24 6	0 033	1.295	85.59	66.49	61.00	35.84	64.16
1119	1st 100	6.09	2.89	2.12	23.0	0.031	1.302					
	2d 100	6.10	2.90	2.10	24.0	.032	1.313					
	3d 100	6.07	2.90	2.09	23.0	.031	1.324					
	4th 100	6.10	2.89	2.11	24.0	.032	1.335					
	5th 100	6.13	2.88	2.12	23.0	.032	1.306					
Av.....	500	6.10	2.89	2.11	23.4	0.032	1.316	89.17	69.27	67.84	35.82	64.18
1121	1st 100	6.07	2.85	2.13	21.5	0.028	1.301					
	2d 100	6.01	2.84	2.11	21.0	.028	1.308					
	3d 100	6.08	2.92	2.08	22.5	.030	1.302					
	4th 100	6.00	2.86	2.10	22.0	.028	1.297					
	5th 100	6.03	2.88	2.09	22.5	.029	1.306					
Av.....	500	6.04	2.87	2.10	21.9	0.029	1.303	82.95	64.45	60.84	35.96	64.04
1125	1st 100	6.24	3.03	2.06	23.5	0.033	1.359					
	2d 100	6.27	2.99	2.10	24.0	.032	1.348					
	3d 100	6.26	3.01	2.08	24.0	.032	1.358					
	4th 100	6.30	3.00	2.10	24.0	.033	1.357					
	5th 100	6.32	3.01	2.10	25.0	.033	1.368					
Av.....	500	6.28	3.01	2.09	24.1	0.033	1.358	86.81	67.44	61.93	35.84	64.16
1145	1st 100	6.41	3.19	2.00	28.0	0.036	1.218					
	2d 100	6.41	3.16	2.02	29.5	.034	1.222					
	3d 100	6.40	3.18	2 01	27.7	.035	1 231					
	4th 100	6.41	3.17	2.02	27.5	.035	1.227					
	5th 100	6.45	3.15	2.04	28.9	.036	1.227					
Av.....	500	6 42	3 17	2.09	28.8	0.035	1.225	81.67	63.45	58.14	35.12	64.88
1149	1st 100	6.02	2.88	2.09	23.0	0.031	1.361					
	2d 100	6.02	2.85	2.11	21.5	.031	1.361					
	3d 100	5.99	2.85	2.10	21.5	.030	1.258					
	4th 100	6.00	2.85	2.10	22.0	.031	1.358					
	5th 100	6.00	2.87	2.09	22.0	.031	1.362					
Av.....	500	6.01	2.86	2.10	22.0	0.031	1.360	89.91	69 85	63 58	35.04	64.96

TABLE I—*Concluded.*

No.	No. grains.	Av. length (mm.)........	Av. width (mm.).........	Ratio length to width....	Av. volume (cu. mm.)....	Av. weight (g.).........	Av. specific gravity......	Av. volume-weight.			Packing quality.	
								Grams per 100 cc..	Lbs. per (packed) bushel...........	Lbs. per (struck) bushel..........	Per cent vol. in 100 cc. not occupied by grain....	Per cent vol. of grain in 100 cc..
1150	1st 100 2d 100 3d 100 4th 100 5th 100	6.23 6.24 6.26 6.21 6.27	2.85 2.88 2.88 2.90 2.89	2.18 2.16 2.17 2.14 2.16	23.5 23.5 24.0 23.5 23.9	0.032 .032 .033 .033 .033	1.362 1.331 1.358 1.342 1.358					
Av.....	500	6.24	2.88	2.16	23.7	0.033	1.350	87.84	67.64	62.33	35.64	64.36
1151	1st 100 2d 100 3d 100 4th 100 5th 100	6.04 6.01 5.99 6.04 6.03	2.81 2.77 2.78 2.81 2.83	2.15 2.17 2.15 2.15 2.14	18.5 18.1 18.5 18.5 18.0	0.024 .024 .023 .023 .023	1.283 1.284 1.290 1.280 1.272					
Av.....	500	6.02	2.80	2.15	18.3	0.023	1.282	77.02	59.84	58.87	40.28	59.72
1152	1st 100 2d 100 3d 100 4th 100 5th 100	6.10 6.10 6.11 6.08 6.10	2.62 2.59 2.60 2.62 2.58	2.33 2.35 2.35 2.32 2.36	19.0 18.0 18.5 19.0 18.5	0.026 .026 .026 .026 .025	1.359 1.357 1.362 1.365 1.373					
Av.....	500	6.10	2.60	2.34	18.6	0.026	1.363	88.74	68.94	63.55	35.24	64.76
1068-2	1st 100 2d 100 3d 100 4th 100 5th 100	6 34 6.29 6.34 6.30 6.33	2.89 2.88 2.89 2.86 2.90	2.19 2.18 2.21 2.20 2.18	21.0 20.9 20.7 20.1 22.0	0.029 .028 .028 .029 .030	1.344 1.343 1.350 1.337 1.341					
Av.....	500	6.32	2.88	2.19	20.9	0.029	1.343	81.45	63.28	62.15	36.24	63.76

In a similar way, the mean kernel-*width* for each race was also determined, upon another slightly differently constructed measuring board. (Plate VII.) It was found that the variations in averages among the five different hundreds of each lot were so slight that in general a lesser number than 500 would have sufficed. However, this number was adhered to in the determination of the averages in question for the entire series of fifty-two races.

These length and breadth measurements were then combined in the form of the ratio of length to width for each race, and taken as a form-factor—a large ratio denoting a long grain and a small ratio a short grain, as a matter of course.

Each separate lot, for which mean lengths and widths of the grain had been determined, was also used in the determination of mean kernel volume. This was done by pouring each lot of 100 kernels into a very accurately calibrated burette, previously filled with 95 per cent alcohol up to an observed point. The volume of displacement of the alcohol gave the data for determining the average kernel volume, expressed in cubic millimeters, and furnished a means of differentiating, say, two races having the same $\frac{\text{length}}{\text{width}}$ ratios, but in which the kernels were of different average sizes. Here also the mean volumes for each of the 500-kernel lots in the different races are exceedingly uniform. (See table I.)

Other factors in the form of kernel, such as the third dimension, or the distance from the plane of the "crease" or groove, perpendicularly to the point of greatest thickness of the kernel, and the form and dimensions of the crease itself, were not determined, owing to special difficulties in the way of ascertaining them. Nor was any way found for quantitatively measuring, without too laborious detail, the outline of the kernel, which varied from broad-oval, tapering equally toward both ends, to linear-oblong, or an obovate form, tapering toward one end. All of these differences in the shape of the kernel were left to be expressed by mean $\frac{\text{length}}{\text{width}}$ ratios and by mean volumes.

The volume-weight of the kernels of each race was then determined by weighing as much grain as could possibly be packed into a 250 cc. graduate, the packing being effected by vigorous tamping of the graduate a given number of times for each fractional portion of its contents as the same was put in. This volume-weight in grams per 100 cc. will be taken converted into terms of pounds per bushel for the purpose of this paper.

The amount of unoccupied air space left among the kernels of the packed grain was then determined in the case of each of the fifty-two cases in the experiment, by filling the graduate in which the grain had been packed as described, with 95 per cent alcohol. The amount of alcohol thus delivered from the burette, and necessary to exactly cover the grain, reduced to a basis of 100 cc. and subtracted from 100, gave exactly the volume in percentage of 100 cc. of actual solid grain material in each instance.

There were thus at hand data for determining the relation between any specific type of kernel as expressed in terms of the $\frac{\text{length}}{\text{width}}$ ratio and the average kernel-volume on the one hand, and the percentage volume of grain in 100 cc. on the other; and between all of these factors on the one hand and the bushel-weight on the other.

Assembling the data given in table I in such manner as to bring out these relationships, we have:

TABLE II.

Pedigree No.	Average kernel volume (cu. mm).	Average kernel weight (grams).	Volume-weight of grain.			Packing quality.	
			Grams per 100 cc.	Lbs. per bushel (packed).	Lbs. per bushel (struck).	Air space in 100 cc. unoccupied by grain.	Per cent vol. of grain in 100 cc.
1071	14.6	0.019	80.57	62.59	55.99	38.48	61.52
907	15.0	.020	84.21	65.42	57.41	36.76	63.24
1069	15.0	.020	80.86	62.82	58.92	38.08	61.92
418-6	16.0	.021	84.99	66.03	62.26	34.64	65.36
1082-1	16.1	.021	82.99	64.47	57.76	38.64	61.36
860	16.4	.022	83.89	65.17	59.69	36.51	63.49
985	16.7	.023	88.27	68.58	63.39	35.08	64.92
778	17.0	.023	86.17	66.94	60.77	37.13	62.87
748	17.3	.024	83.77	65.08	58.11	37.60	62.40
1059-1	17.5	.023	81.15	63.04	57.05	39.23	60.77
983	17.9	.024	86.17	66.94	60.69	35.52	64.48
1106	17.9	.024	82.31	63.93	57.73	38.30	61.70
921	18.0	.024	78.64	61.09	56.48	38.36	61.64
1023	18.0	.025	79.04	61.40	58.87	41.09	58.91
861	18.1	.024	84.16	65.38	59.16	37.17	62.83
1114	18.2	.023	84.89	65.95	60.16	36.10	63.90
1018	18.3	.025	86.41	66.85	60.63	36.64	63.36
115'	18.3	.023	77.02	59.84	58.87	40.28	59.72
800	18.6	.025	85.06	66.87	62.75	36.60	63.40
1090	18.6	.025	85.99	66.80	57.78	37.84	62.16
1152	18.6	.026	88.74	68.94	63.55	35.24	64.76
1014	19.2	.025	79.27	61.58	55.50	37.88	62.12
1081	19.7	.026	86.32	67.06	62.55	37.94	62.06
1110	19.8	.027	83.66	64.99	59.30	37.23	62.77
819	19.9	.027	83.58	64.84	59.48	36.52	63.48
898	20.0	.027	83.01	64.49	59.33	35.85	64.15
1074	20.0	.028	88.59	68.82	62.31	35.84	64.16
994	20.3	.027	82.18	63.84	58.06	36.66	63.34
1016	20.5	.028	80.78	62.76	56.43	37.94	62.06
854	20.9	.028	83.70	65.02	59.21	37.47	62.53
1064	20.9	.030	88.60	68.87	62.05	36.67	63.33
1068-2	20.9	.029	81.45	63.28	62.15	36.24	63.76
951	21.0	.028	87.33	67.84	58.94	37.51	62.49
1078	21.1	.028	85.85	64.75	57.56	37.52	62.48
1008	21.6	.024	86.06	66.86	61.86	36.20	63.80
1113	21.8	.030	85.93	66.76	61.22	36.87	63.13
1121	21.9	.029	82.95	64.45	60.84	35.96	64.04
1149	22.0	.031	89.91	69.85	63.58	35.04	64.96
927	22.4	.030	85.41	66.85	60.31	35.48	64.52
1112	22.7	.032	88.64	68.87	62.84	35.76	64.24
1119	23.4	.032	89.17	69.27	67.34	35.82	64.18
1066	23.6	.033	91.36	70.98	65.25	34.90	65.10
1150	23.7	.033	87.84	67 64	62.33	35.64	64.36
1125	24.1	.033	86.81	67.44	61.93	35.84	64.16
1111	24.3	.033	86.81	67.44	62.47	34.68	65.32
1116	24.6	.033	85.59	66.49	61.00	35.84	64.16
932	24.9	.034	88.77	68.96	61.97	34.52	65.48
1105	24.9	.034	87.62	68.07	63.21	34.12	65.88
1115	25.3	.034	84.63	65.75	60.45	35.50	64.50
1040	25.8	.034	80.53	65.18	54.78	39.60	60.40
940	26.3	.037	88.88	69.05	63.23	35.17	64.83
1145	28.3	.035	81.67	63.45	58 14	35.12	64.88

In the table (II) we have the races under investigation arranged in the order of increase of their average kernel-volumes. By reference to the data in the succeeding columns of this table, the relation is shown between the average individual kernel-volume on the one hand, and on the other the volume-weight of grain, and what for lack of a better term is designated as "packing quality." The gross bearing of average kernel-volume upon the "packing quality" of the grain, as expressed by the percentage volume of grain capable of being packed into 100 cc., is shown in plate VIII. Taking as abscissæ the average kernel-volumes, and as ordinates the percentage volume of grain in 100 cc., it is clearly shown that, without reference to the $\frac{\text{length}}{\text{width}}$ ratios of the kernels, and without regard to the average kernel-weights, there is a steady and uniform rise in the percentage of solid grain material that will go into a given cubic volume of space, as the average kernel-volumes rise from 14 to 28 cubic millimeters.

The data plotted are shown in two groups, those races (twenty-seven in number) having $\frac{\text{length}}{\text{width}}$ ratios of from 1.88 to 2.14 millimeters being designated by circles, and those races (twenty-five in number) having $\frac{\text{length}}{\text{width}}$ ratios of from 2.15 to 2.84 millimeters being indicated by crosses. By thus differentiating the races having kernels with low ratios (short kernels) from those with high ratios (long kernels), it is readily seen that the combination of short kernels with large volumes is the more frequent one, and that there is a more uniform rise in the packing quality of the grain where the increasing kernel-volumes are accompanied by low $\frac{\text{length}}{\text{width}}$ ratios. It is sufficiently apparent from this plotting alone that the type of kernel to breed for is one having a low $\frac{\text{length}}{\text{width}}$ ratio combined with a maximum average kernel-volume. Considering now the relation between the $\frac{\text{length}}{\text{width}}$ ratio of the kernels and the packing quality of the grain, we have the data of table I plotted in plate IX. No attempt has been made to calculate an equation to express the curve according to which these individual

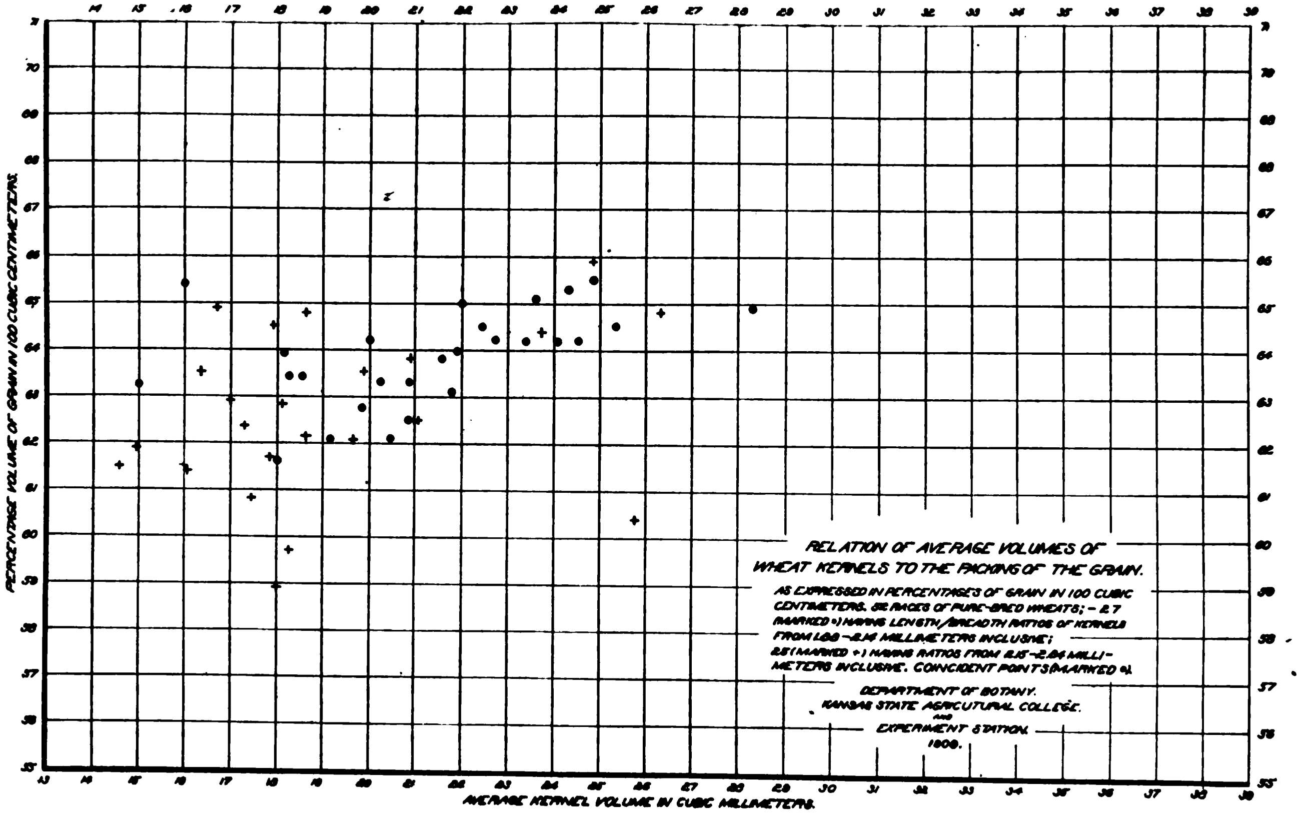

PLATE VIII. Relation of average volumes of wheat kernels to the packing of the grain.

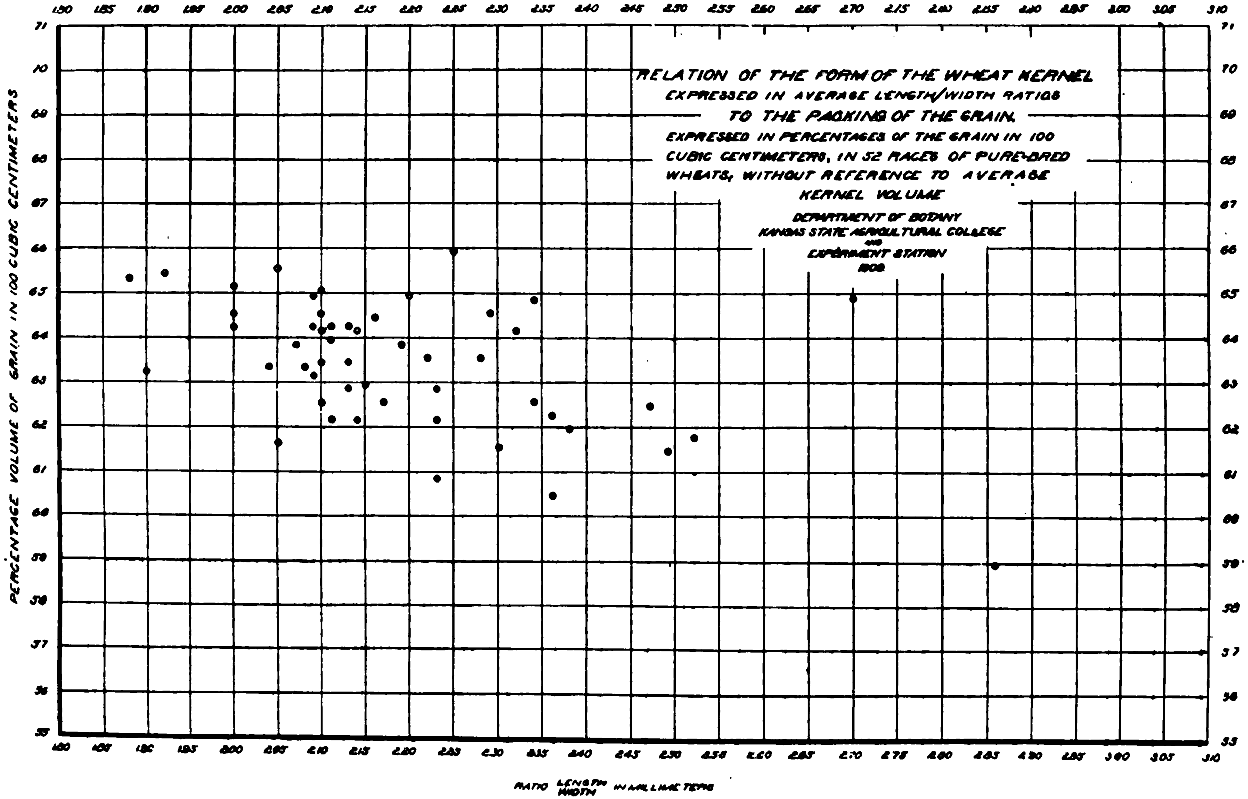

PLATE IX. Relation of the form of the wheat kernel to the packing of the grain.

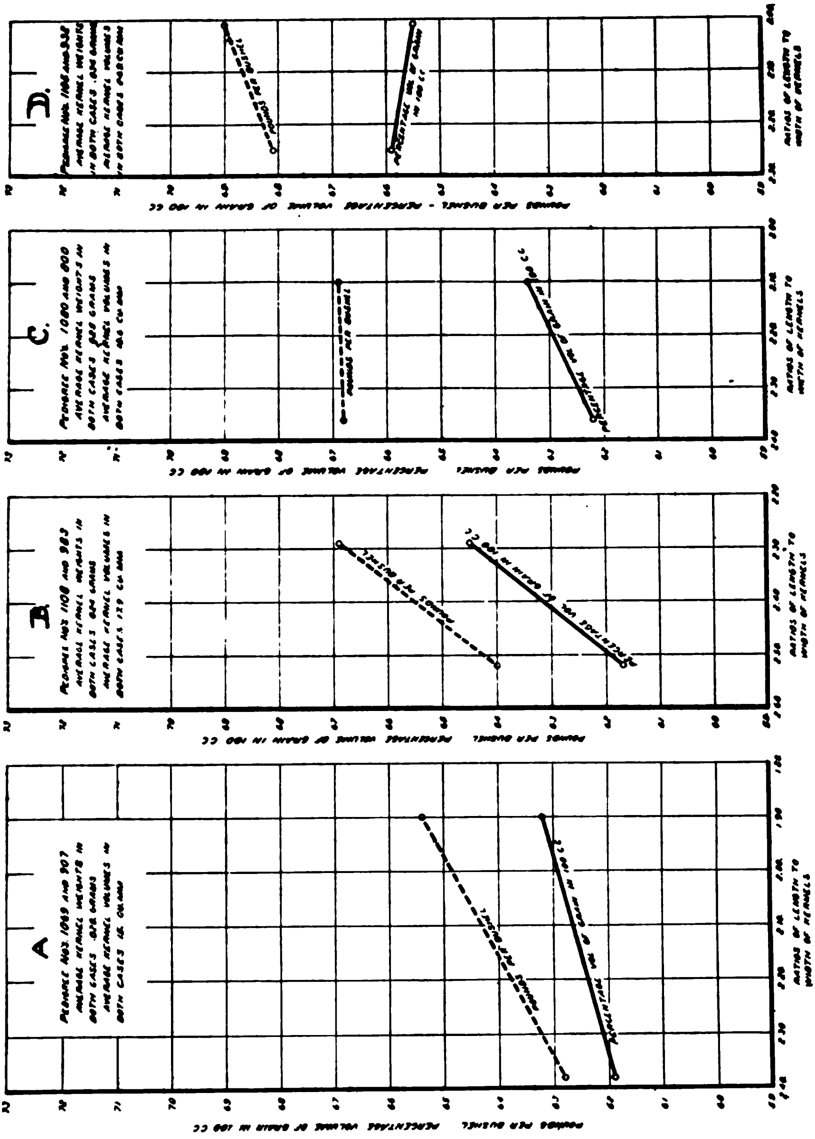

PLATE X. Relation of cubic volume of grain to bushel-weight.

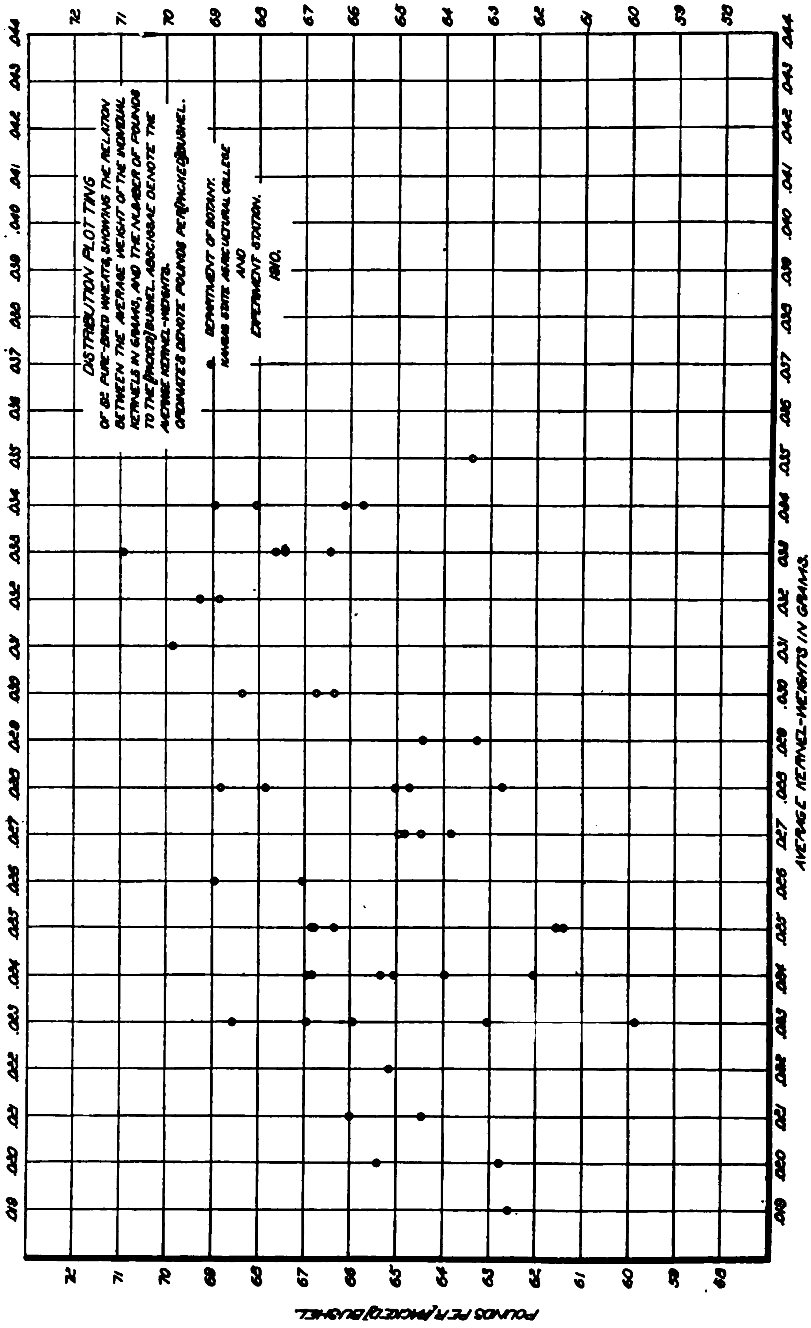

PLATE XI. Relation of kernel-weight to bushel-weight.

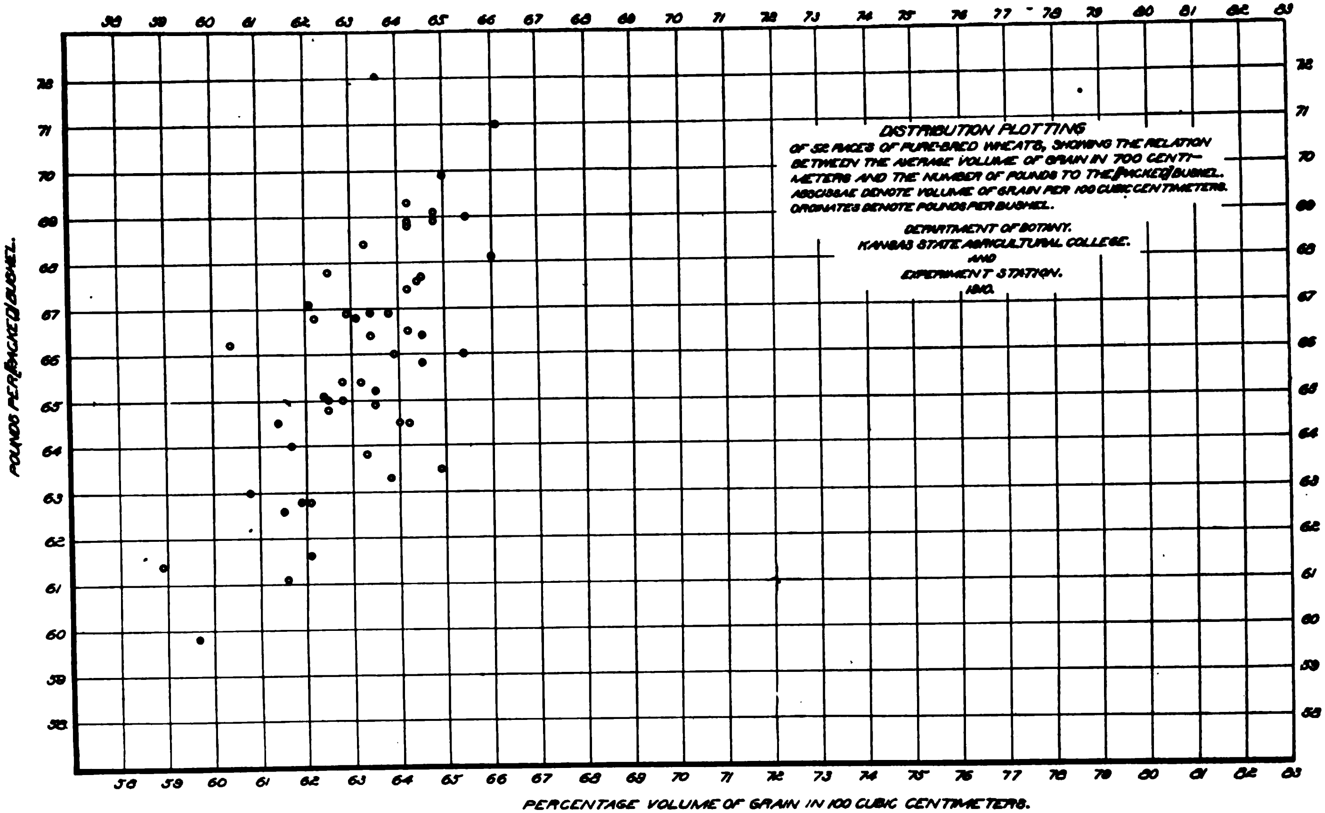

Plate XII. Relation of percentage volume of grain to bushel-weight.

data fall, but simple inspection shows that such an equation would be for a straight line, and that the curve falls from the low to the high ratios. In other words, the plot clearly shows that with an increased $\frac{\text{length}}{\text{width}}$ ratio—*i. e.*, a larger kernel—the percentage volume of grain in 100 cc. falls off absolutely, and irrespective of the average kernel-volumes, thus corroborating the conclusion derived from the data in plate VIII.

Referring again to table II, it will be noted that four pairs of wheat races occur, indicated in black-face type, in which, for each pair, identical kernel-volumes and identical kernel-weights exist. By having thus eliminated the variables of weight and volume, it is possible to analyze more exactly the relation between $\frac{\text{length}}{\text{width}}$ ratios of the kernels on the one hand, and both volume-weight (pounds per bushel) and percentage volume of grain in 100 cc. (packing quality) on the other. This relation is exhibited by the plotting in plate X.

In plate X we have the four pairs of cases given in table II, where identical kernel-volumes and kernel-weights occur in each pair, respectively. These pairs are arranged in four successive plots on the plate in the order of increasing average volume of the kernels of the pairs. The abscissæ indicate the $\frac{\text{length}}{\text{width}}$ ratios of the kernels in decreasing order for each pair. The ordinate figures express conveniently two relations, viz., pounds per bushel and percentage volume of grain in 100 cc. The effect of high and low $\frac{\text{length}}{\text{width}}$ ratios upon each of these factors is expressed separately by the two groups of each plot. It will be seen that in three out of the four pairs of cases, where identical kernel-volumes and kernel-weights exist for each pair, that increased percentages of grain in 100 cc. follow the progression from high to low ratios. It also appears that increased bushel-weight accompanies without exception that member of each of the four pairs having the lower ratio. The general shifting of the pairs up on the ordinate scale from plot A to plot D may be due in part to progressively increasing average kernel-weights, since the latter run in an increasing series 0.020, 0.025 and 0.034 for the plots from A to D. It is more likely, however, that the predominant influence is that of average kernel-volume. The demonstration of the general importance of this factor in plate VIII leads to the conclusion that in the four pairs exhibited here, where a rise from A to D is indicated with practically no exception, when each member of the pair is followed successively through the four plots for both percentage volume of grain and pounds per bushel, that this is largely to be charged to the rise in kernel-volume from 15 cu. mm. in A to 24.9 cu. mm. in D. This rise in the kernel-volume is moreover much more rapid than the corresponding rise in kernel-weight.

In table III, which follows, the data of averages given in table I are again rearranged, to show the absolute relation between average weight of individual kernels in the different races under experiment and the volume-weight and packing quality of the grain, the arrangement being in the order of increasing average weights of the kernels.

TABLE III.

Pedigree No.	Av. kernel-weight (g.).	Volume-weight of grain.			Packing quality of the grain.	
		Grams per 100 cc.	Lbs. per bushel (packed).	Lbs. per bushel (struck).	Air space in 100 cc. unoccupied by grain.	Per cent vol. of grain in 100 cc.
1071	0.019	80.57	62.59	55.99	38.48	61.52
907	.020	84.21	65.42	57.41	36.76	63.24
1069	.020	80.86	62.82	58.82	38.08	61.92
418-6	.021	84.99	66.03	62.26	34.64	65.36
1082-1	.021	82.99	64.47	57.76	38.64	61.36
860	.022	83.89	65.17	59.69	36.51	63.49
778	.023	86.17	66.94	60.77	37.13	62.87
985	.023	88.27	68.58	63.39	35.08	64.92
1059-1	.023	81.15	63.04	57.05	39.23	60.77
1114	.023	84.89	65.96	60.16	36.10	63 90
1151	.023	77.02	59.84	53.87	40.28	59.72
748	.024	83.77	65.08	58.11	37.60	62.40
861	.024	84.16	65.38	59.16	37.17	62.83
921	.024	78.64	61.09	56.48	38.36	61.64
983	.024	86.17	66.94	60.69	35.52	64.48
1008	.024	86.06	66.86	61.86	36.20	63.80
1108	.024	82.31	63.95	57.73	38.30	61.70
800	.025	86.08	66.87	62.75	36.60	63.40
1014	.025	79.27	61.58	55.50	37.88	62.12
1018	.025	85.41	66.35	60.63	36.64	63.36
1023	.025	79.04	61.40	53.37	41.09	58.91
1080	.025	85.99	66.80	57.78	37.84	62.16
1081	.026	86.32	67.06	62.55	37.94	62.06
1152	.026	88.74	68.94	63.55	35.24	64.76
819	.027	83.53	64.89	59.48	36.52	63.48
893	.027	83.01	64.49	59.33	35.85	64.15
994	.027	82.18	63.84	58.06	36.66	63.34
1110	.027	83.66	64.99	59.30	37.23	62.77
854	.028	83.70	65.02	59.21	37.47	62.53
951	.028	87.33	67.84	58.94	37.51	62.49
1016	.028	80.78	62.76	56.43	37.94	62.06
1074	.028	88.59	68.82	62.31	35.84	64.16
1078	.028	83.35	64.75	57.56	37.52	62.48
1068-2	.029	81.45	63.28	62.15	36.24	63.76
1121	.029	82.95	64.45	60.84	35.96	64.04
927	.030	85.41	66.35	60.31	35.48	64.52
1064	.030	88.00	68.37	62.05	36.67	63.33
1118	.030	85.93	66.76	61.22	36.87	63.13
1149	.031	89.91	69.85	63.58	35.04	64.96
1112	.032	88.64	68.87	62.84	35.76	64.24
1119	.032	89.17	69.27	67.34	35.82	64.18
1066	.033	91.36	70.98	65.25	34.90	65.10
1111	.033	86.81	67.44	62.47	34.68	65.32
1116	.033	85.59	66.49	61.00	35.84	64.16
1125	.033	86.81	67.44	61.93	35.84	64.16
1150	.033	87.84	67.64	62.33	35.64	64.36
932	.034	88.77	68.96	64.07	34.52	65.48
1105	.034	87.62	68.07	63.21	34.12	65.88
1040	.034	80.58	65.18	54.78	39.60	60.40
1115	.034	84.63	65.75	60.45	35.50	64.50
1145	.035	81.67	63.45	58.14	35.12	64.88
940	.037	88.88	69.05	63.23	35.17	64.83

The degree of influence exercised by the average kernel-weight in the gross upon the bushel-weight, may be inferred to some extent from plate XI, in which the abscissæ denote the average kernel-weight in grams and the ordinates indicate the number of pounds to the (packed) bushel. It should be remembered, however, that the variable of increasing volume is also present, and that the plotting therefore cannot show the absolute relation between kernel-weight alone and volume-weight. It is sufficient to call attention to the fact that the relation here is not as close as between kernel-volume and volume-weight as shown in plate VIII.

The prime importance of a well packing type of grain in wheat, so far as the test bushel-weight is concerned, is shown most strikingly in plate XII, where the percentage volumes of grain in 100 cc. are plotted as abscissæ, and the bushel-weights as ordinates. The sharp and close coincidence of good packing quality with high bushel-weight, irrespective of individual kernel-weights, is here strikingly shown.

Finally, in table IV, the fifty-two races of wheat under investigation stand arranged in the increasing order of their $\frac{\text{length}}{\text{width}}$ ratios. Amongst these, the races having coincident ratios are printed throughout in black-face type.

TABLE IV.

Pedigree No.	Av. ratio length to breadth of kernels.	Av. kernel volume (cu. mm.)	Packing quality of grain.		Volume-weight of grain.		
			Air space in 100 cc. unoccupied by grain.	Per cent vol. of grain in 100 cc.	Grams per 100 cc.	Lbs. per bu. (packed).	Lbs. per bu. (struck).
1111	1.88	24.8	34.68	65.32	86.81	67.44	62.47
907	1.90	15.0	36.76	63.24	84.21	65.42	57.41
418-8	1.92	16.0	34.64	65.36	84.99	66.03	62.36
1074	2.02	20.0	35.84	64.16	88.59	68.82	62.31
1066	2.02	23.6	34.90	65.10	91.36	70.96	65.35
1115	2.03	25.3	35.50	64.50	84.63	65.75	60.45
994	2.04	20.3	36.66	63.34	82.18	63.84	58.06
921	2.05	18.0	38.36	61.64	78.64	61.09	56.48
988	2.05	24.9	34.52	65.48	88.77	68.96	64.07
1008	2.07	21.6	36.20	63.80	86.06	66.86	61.86
1064	2.08	20.9	36.67	63.33	88.00	68.37	62.05
1113	2.09	21.8	36.87	63.13	85.93	66.76	61.23
1125	2.09	24.1	35.84	64.16	86.81	67.44	61.93
1145	2.09	26.3	35.12	64.88	81.67	63.45	58.14
800	2.10	18.6	36.60	63.40	86.08	66.87	62.75
854	2.10	20.9	37.47	62.53	83.70	65.03	59.21
1121	2.10	21.9	35.96	64.04	82.96	64.45	60.84
1149	2.10	22.0	35.04	64.96	89.91	69.85	63.58
927	2.10	22.4	35.48	64.52	85.41	66.35	60.31
1114	2.11	18.2	36.10	63.90	84.89	65.95	60.16
1016	2.11	20.5	37.94	62.06	80.78	62.76	56.43
1119	2.11	23.4	35.82	64.18	89.17	69.27	67.34
1018	2.13	18.3	36.64	63.36	85.41	66.35	60.63
1110	2.13	19.8	37.23	62.77	83.06	64.90	59.30
1112	2.13	22.7	35.76	64.24	88.64	68.87	63.84
1014	2.14	19.2	37.88	62.12	79.27	61.58	55.50
1116	2.14	24.6	35.84	64.16	85.59	66.49	61.00
778	2.15	17.0	37.13	62.87	86.17	66.94	60.77
1154	2.15	18.3	40.28	59.72	77.02	59.84	53.37
1150	2.16	23.7	35 64	64.36	87.84	67.64	62.33
951	2.17	21.0	37 51	62.49	87.33	67.84	58.94
1068-2	2.19	20.9	36.24	63.76	81.45	63.28	62.15
935	2.20	16.7	35.08	64.92	88.27	68.58	63.39
819	2.22	19.9	36.52	63.48	83.53	64.89	59.48
1059-1	2.23	17.5	39.23	60.77	81.15	63.04	57.05
861	2.23	18.1	37.17	62.83	84.16	65.38	59.16
1061	2.23	19.7	37.94	62.06	86.32	67.06	62.55
1105	2.25	24.9	34.12	65.88	87.62	68.07	63.21
860	2.28	16.4	36.51	63.49	83.89	65.17	59.69
983	2.29	17.9	35.52	64.48	86.17	66.94	60.69
1071	2.30	14.6	38.48	61.52	80.57	62.59	55 90
898	2.32	20.9	35.85	64.15	83.01	64.49	59.33
1152	2.34	18.6	35.24	64.76	88.74	68.94	63.55
1078	2.34	21.1	37.52	62.48	85.35	61.75	57.56
1060	2.36	18.6	37.84	62.16	85.99	66.80	57.78
1040	2.36	25.8	39.60	60.40	80.53	65.18	54.78
1069	2.38	15.0	38.08	61.92	80.86	62.82	58.82
748	2.47	17.3	37.60	62.40	83.77	65.08	58.11
1062-1	2.49	16.1	38.64	61.36	82.99	64.47	57.76
1108	2.52	17.9	38.30	61.70	82.31	63.95	57.73
940	2.70	26.3	35.17	64.83	88.88	69.05	63 23
1023	2.84	18.0	41 09	58.91	79 04	61.40	53.37

These eleven groups, having from two to five members each, having identical ratios within the group, are shown in succession on plates XIII, XIV, XV and XVI. In these plates the ratios run from 2.02 to 2.36. For each plate the average kernel-volumes in cubic millimeters are plotted as abscissæ, while the ordinates are of three sets. The upper (integral) ordinates have a dual value, indicating throughout all of the plots in the four plates both pounds per bushel and percentage volume of grain in 100 cc. The lower (decimal) ordinates denote average kernel-weights in grams. We are thus enabled to present in each plot of the four plates three separate graphs, which exhibit side by side, under identical conditions as regards $\frac{\text{length}}{\text{width}}$ ratios, the relation which volume-weight, kernel-weight and percentage volume of grain in 100 cc. all bear to one another, where increasing kernel-volumes are denoted by the abscissæ.

It will be understood, in explanation of these plates, that each individual case in each plot is treated as though it were a separate moment on an individual variation curve. Take, for example, the case of the lower graph in plate XIV, which gives the plotting of the percentage volume of grain in 100 cc. for five successive races of wheat—Nos. 800, 854, 1121, 1149 and 927—in the order of the increasing values of their kernel-volumes as denoted by the abscissæ. Above this graph the same races follow in the same order in the other two graphs, but the ordinates denote average kernel-weight in grams and pounds per bushel in each case, respectively. It is manifestly impossible, without more data, to speak positively regarding the exact mathematical relation that may be found to exist in the case of wheat between the percentage volume of grain in a given cubic space and the volume-weight as expressed in pounds per bushel. It is sufficiently evident that an exceedingly close relation does exist between the two. (See plate XII.) A close inspection of the series of plates further reveals the fact that the rise and fall of the graph for bushel-weight, while generally accompanied by a closely corresponding rise and fall of the percentage volume of grain in 100 cc., is not accompanied by a similar deflection of the graph for individual kernel-weight. In plate XI the doubtful and uncertain bearing of the average individual kernel-weight upon the bushel-weight has been in-

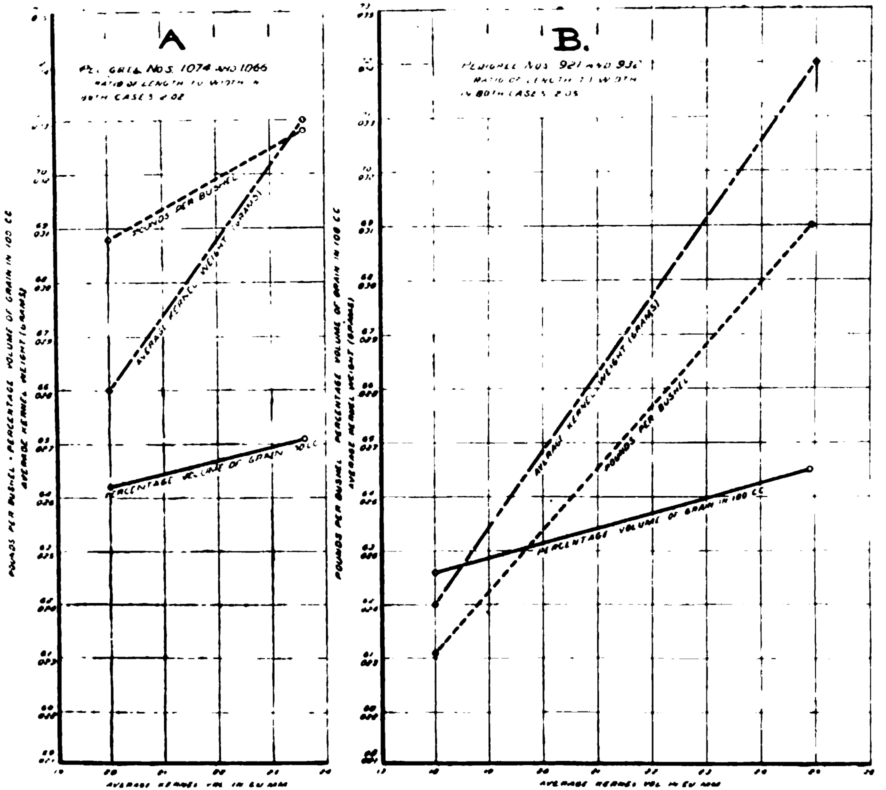
A
Pl. Gr. & Nos. 1074 and 1066
Ratio of length to width in both cases 2.02
Pounds per bushel
Average kernel weight (grams)
Percentage volume of grain 100 cc
Pounds per bushel · Percentage volume of grain in 100 cc
Average kernel weight (grams)
Average kernel vol. in cu mm
B.
Pedigree Nos. 921 and 936
Ratio of length to width in both cases 2.05
Average kernel weight (grams)
Pounds per bushel
Percentage volume of grain in 100 cc
Pounds per bushel Percentage volume of grain in 100 cc
Average kernel weight (grams)
Average kernel vol. in cu mm

PLATE XIII.

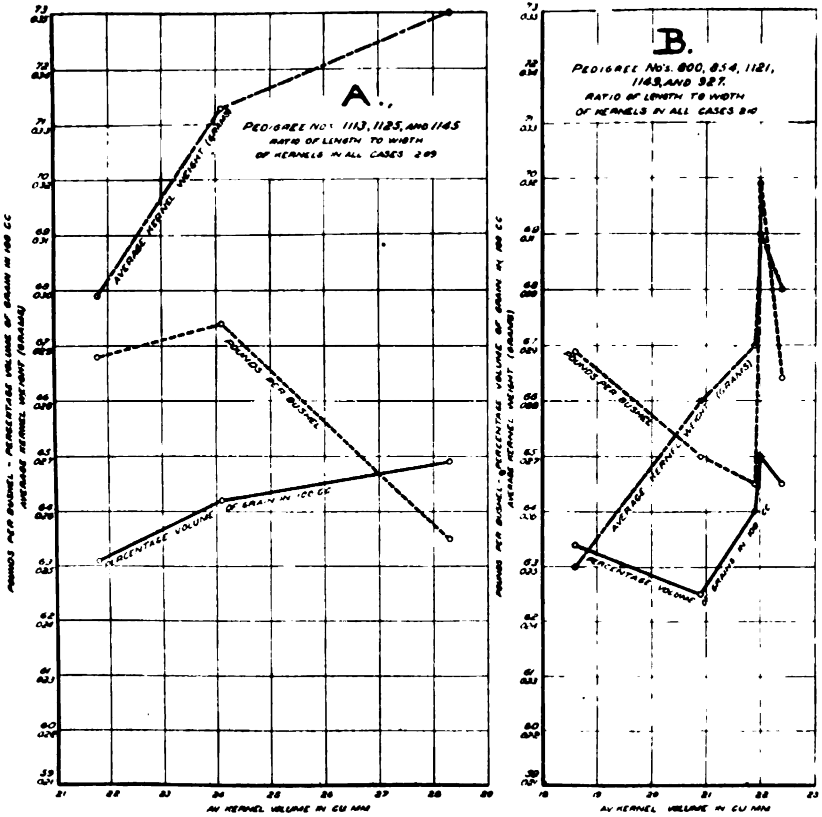
A.
PEDIGREE NO'S 1113, 1125, AND 1145
RATIO OF LENGTH TO WIDTH
OF KERNELS IN ALL CASES 2.09
AVERAGE KERNEL WEIGHT (GRAMS)
POUNDS PER BUSHEL
PERCENTAGE VOLUME OF GRAIN IN 100 CC
POUNDS PER BUSHEL - PERCENTAGE VOLUME OF GRAIN IN 100 CC
AVERAGE KERNEL WEIGHT (GRAMS)
73 0.35
72 0.34
71 0.33
70 0.32
69 0.31
68 0.30
67 0.29
66 0.28
65 0.27
64 0.26
63 0.25
62 0.24
61 0.23
60 0.22
59 0.21
21
22
23
24
25
26
27
28
29
AV KERNEL VOLUME IN CU MM
B.
PEDIGREE No's. 800, 854, 1121,
1143, AND 927.
RATIO OF LENGTH TO WIDTH
OF KERNELS IN ALL CASES 2.10
POUNDS PER BUSHEL
AVERAGE KERNEL WEIGHT (GRAMS)
PERCENTAGE VOLUME
GRAINS IN 100 CC
POUNDS PER BUSHEL - PERCENTAGE VOLUME OF GRAIN IN 100 CC
AVERAGE KERNEL WEIGHT (GRAMS)
73 0.35
72 0.34
71 0.33
70 0.32
69 0.31
68 0.30
67 0.29
66 0.28
65 0.27
64 0.26
63 0.25
62 0.24
61 0.23
60 0.22
59 0.21
18
19
20
21
22
23
AV KERNEL VOLUME IN CU MM

PLATE XIV.

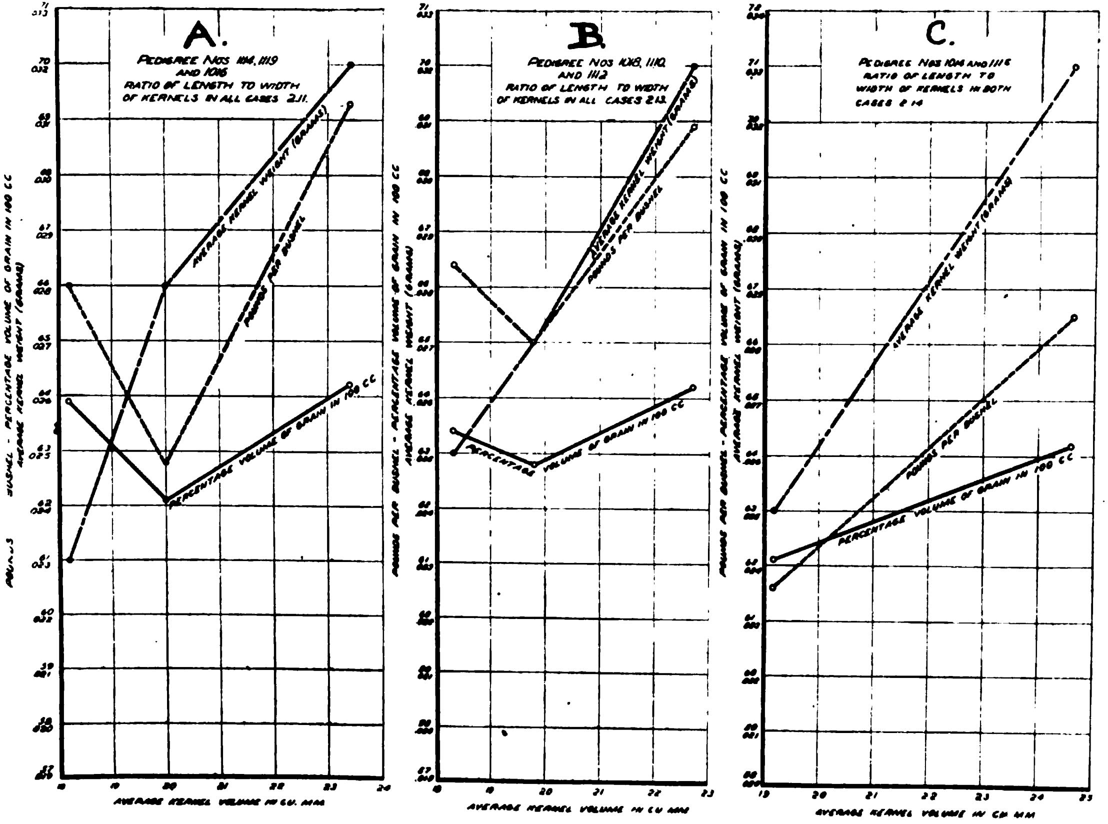
A.
Pedigree Nos 1114, 1119 and 1016
Ratio of length to width of kernels in all cases 2.11.
Average kernel weight (grams)
Pounds per bushel
Percentage volume of grain in 100 cc
Pounds per bushel - Percentage volume of grain in 100 cc
Average kernel weight (grams)
Average kernel volume in cu. mm
B.
Pedigree Nos 1018, 1110 and 1112
Ratio of length to width of kernels in all cases 2.13.
Average kernel weight (grams)
Pounds per bushel
Percentage volume of grain in 100 cc
Pounds per bushel - Percentage volume of grain in 100 cc
Average kernel weight (grams)
Average kernel volume in cu mm
C.
Pedigree Nos 1014 and 1115
Ratio of length to width of kernels in both cases 2.14
Average kernel weight (grams)
Pounds per bushel
Percentage volume of grain in 100 cc
Pounds per bushel - Percentage volume of grain in 100 cc
Average kernel weight (grams)
Average kernel volume in cu mm

PLATE XV.

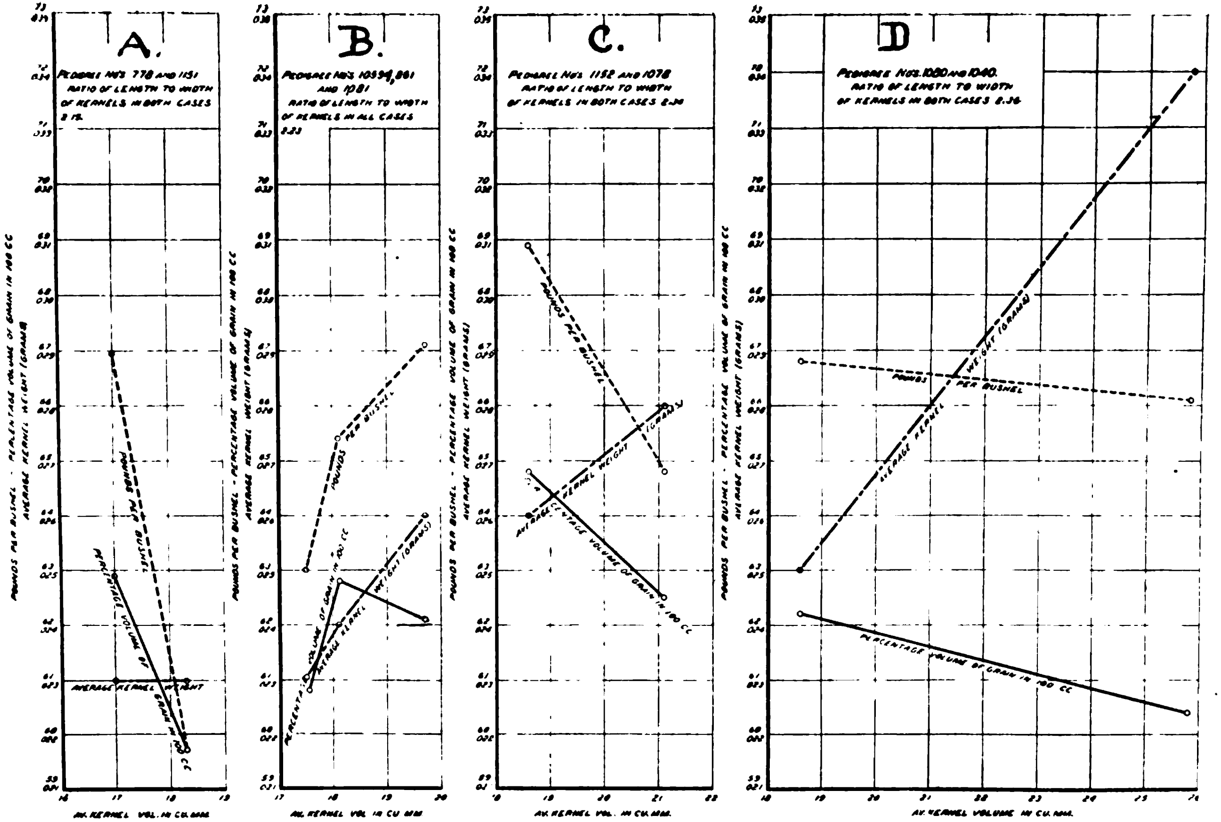
A.
PEDIGREE NO'S 778 AND 1151
RATIO OF LENGTH TO WIDTH
OF KERNELS IN BOTH CASES
2.15.
POUNDS PER BUSHEL
PERCENTAGE VOLUME OF GRAIN IN 100 CC
AVERAGE KERNEL WEIGHT
B.
PEDIGREE NO'S 1059,861
AND 1081
RATIO OF LENGTH TO WIDTH
OF KERNELS IN ALL CASES
2.23
POUNDS PER BUSHEL
PERCENTAGE VOLUME OF GRAIN IN 100 CC
AVERAGE KERNEL WEIGHT (GRAMS)
C.
PEDIGREE NO'S 1152 AND 1078
RATIO OF LENGTH TO WIDTH
OF KERNELS IN BOTH CASES 2.30
POUNDS PER BUSHEL
AVERAGE KERNEL WEIGHT (GRAMS)
PERCENTAGE VOLUME OF GRAIN IN 100 CC
D
PEDIGREE NO'S. 1080 AND 1040.
RATIO OF LENGTH TO WIDTH
OF KERNELS IN BOTH CASES 2.36
AVERAGE KERNEL WEIGHT (GRAMS)
POUNDS PER BUSHEL
PERCENTAGE VOLUME OF GRAIN IN 100 CC
POUNDS PER BUSHEL - PERCENTAGE VOLUME OF GRAIN IN 100 CC
AVERAGE KERNEL WEIGHT (GRAMS)
AV. KERNEL VOL. IN CU. MM.

PLATE XVI.

dicated. There seems, moreover, to be a rather general tendency for the percentage volume of the grain in 100 cc. and the bushel-weight to rise together with increasing volumes of the individual kernels in the plots for the low ratios (2.02 to 2.14), and to fall in the plots for the high ratios (2.15 to 2.36). This also is irrespective of the average kernel-weight, which latter practically uniformly rises with the increase in kernel-volume in the case of all the ratios. There are, of course, cases which conflict. So far as a general conclusion can be inferred from the data thus far, it is as follows:

Bushel-weight is closely correspondent to the percentage volume of grain contained in a cubic volume of space, with an exact mathematical relation to be established from further data. This relation is practically unaffected by the factor of average kernel-weight. There is a general tendency for both of the above factors to rise in value with increasing average volume of individual kernels, *where the* $\frac{\text{length}}{\text{width}}$ *ratios of kernels is low,* and to fall correspondingly where the same is high.

An investigation of some 250 additional pure races of wheat with respect to all of these relations is now nearly completed, and the data derived therefrom will be included in a future bulletin.

The final conclusions from all of the experimental work on the form-factors of the wheat kernel are:

1. A difference of at least as high as three pounds per bushel may exist between different pure-bred wheats *having identical average kernel-volume and kernel-weight,* and which is due entirely to the superior packing quality of one *type* of kernel over another. (See table II, cases of pairs 906-1069, 983-1108, and plate X, A and B.) In each of these cases the higher member of the pair *is the one having the lower* $\frac{\text{length}}{\text{width}}$ ratio. This indicates that, *all other conditions being equal,* a difference of at least three pounds to the bushel in the test weight can be gained by breeding for short-kernelled races of wheat. When other factors than ratio are considered, it has been found that as much as seven pounds per bushel may be gained by breeding for specific types of kernel.

This difference would unquestionably effect a difference in the grading in many instances. It is of course well known that the sort of manipulation given the grain tester may make a difference of as much as five pounds in the test reading. Even in cases where such manipulation is possible and is practiced to the disadvantage of the wheat grower, nevertheless he cannot but profit through having a variety of wheat which, by reason of the type of the kernel, will gain at least three pounds in the tester over other varieties and types of wheat, under any sort of manipulation whatever. Assuming perfect fairness in the handling of the tester, there is yet every reason for the grower to produce a wheat that will inevitably test high.

2. Where the $\frac{\text{length}}{\text{width}}$ ratios of the kernels remain the same, the higher bushel-weights generally follow the higher kernel-volumes, except in the higher ratios, where the reverse is the case. This indicates that the short type of kernel with high volume is the type to breed for to secure high grading, other things being equal.

3. In general, wheats having low $\frac{\text{length}}{\text{width}}$ ratios are the best packers, and give the highest test bushel-weights.

4. In general, wheats having high average kernel-volumes yield the highest bushel-weights; especially, as before stated, when combined with low ratios.

5. There is a very close dependence of the bushel-weight on the percentage volume of grain in the measure, irrespective of the average kernel-weights.

6. The writer's conclusion from the investigation herein presented, therefore, is that in a just and scientific system of market grading of wheat the percentage volume of grain in a packed measure would be superior, as a basis for establishing a grade, to the present system of grading by test bushel-weight.

In such a system, the grain should be run in a continuous and mechanically distributed stream into a standardized liter measure, which, mounted on a mechanical shaker, would shake or tamp the grain down as it entered. Into this packed measure of grain, ordinary denatured alcohol should be run from a container above, until the surface of the alcohol reaches the level of the surface of the packed grain. Then the amount of alcohol required to cover the grain would be the equivalent of the cubic volume of air space displaced in the measure, and which the wheat itself did not fill. The difference between this amount of alcohol, in cubic centimeters, and 1000 cc.—the volume of the standard measure—would give the actual volume of wheat that had been packed into the measure. Upon the amount of solid grain as determined in this way, and expressed in percentages of 1000 cc., the grading of the grain would rest.

The grain should clearly be cleaned before being graded. This, however, even now, under the present test bushel-weight system, is practiced by the Minnesota State Grain Inspection Department for all grain officially graded there.

Other qualitative factors, such as color, bleached condition, etc., could be passed upon of course as usual, and would be included in the determination of the grade as at present.

The establishment of grades upon the actual percentage-volume of packed wheat in the standard measure would, as the writer's investigations show, inure to the mutual advantage of the wheat grower and of the miller. The wheat raiser would gain by eliminating the fluctuations in the bushel-weight as ascertained by the tester, due not merely to intentional manipulation but to a number of accidental causes.

When we consider that a packed bushel of wheat contains a million or more grains, the importance of such a neglected feature as the crease comes in for consideration. The writer finds that the width and depth of the crease in wheat, as well as its general contour, are characteristic and specific for different pure-bred races of wheat. Plainly, wheat that has a wide, deep crease in the kernel as a race characteristic, will give a lower percentage of solid grain in a measure than a race with a crease almost obliterated, such as some of our pure-bred races possess. Under the proposed system of grading, a grower of wheat with a shallow crease would receive in exact accordance with the superiority of his wheat in this respect. Wheat with a wide deep crease would fall off proportionately in the grading, as also would shrivelled wheat. Indeed, this method would give an exact quantitative measure of value for shrivelled wheat, forcing it automatically, by its lower percentage volume, into one of the lower grades.

So far as the miller is concerned, the proposed method of percentage-volume grading would be to his advantage. For milling purposes, a rather short plump kernel is preferred to a long slender one, on account of the greater amount of flour in proportion to the bran which such a type affords. Now since, as has been shown, the short-kernelled races—*i. e.*, those with low $\frac{\text{length}}{\text{width}}$ ratios—give the highest percentage volume, especially when taken combined with the feature of large average kernel-volume, it is clear that such types of wheat would inevitably grade highest according to this method. This would naturally lead to the growing of wheats with such a kernel to the exclusion of others, which certainly would be to the satisfaction of the mills, while being more profitable to the growers. So far as the matter of crease is concerned, it has already been stated that a type of wheat having a deep crease is undesirable to the millers, on account of the quantity of "crease dirt" that such a type of berry carries, as well as because of the fact that a berry with a deep crease gives more bran in proportion to the flour than does one with a shallow crease. For both of these reasons it is desirable to improve the wheat kernel by eliminating the crease so far as possible. Now, in the proposed method of grading on the basis of percentage volume of grain, a type of wheat with a deep or broad crease would grade lower than a type having a very shallow crease, because of the greater amount of waste air space in the measure. Consequently, such a method of grading as is herein proposed would put a premium on securing and growing types of wheat having a berry with a minimum amount of crease. In the writer's experience with pure-bred wheats at this Experiment Station, it has been found that different races are as distinctively marked in respect to the type of the crease as in respect to other characters of the grain or of the plant. It is therefore perfectly possible to separate out and grow for profit those races of hard winter wheats that have a very shallow crease, and to maintain them.

In the practical application of the principle of grading herein discussed, the element of cost is important. The cost of denatured alcohol at wholesale figures is forty-four cents per gallon in barrel lots f. o. b. place of manufacture. To ascertain how much alcohol is used in this grading method, *i. e.*, how much is lost by absorption and adhesion to grain, a test was made as follows: An accurate 1000 cc. graduate was packed with grain, tamping in the usual manner. Alcohol was then poured in until it barely covered the top of the grain, the amount of the alcohol thus used being carefully measured. This amount, of course, indicated the volume of air expelled from around the kernels—the difference from 1000 cc. being the percentage volume of grain contained in one liter. The alcohol was then carefully drained off, and the amount recoverable in this way was also measured. In this manner the amount of alcohol lost in the operation was determined. The following table gives the results obtained with ten different varieties of wheat from the one-liter sample used of each:

TABLE V.

No.	Wt. (g.) of packed grain in 1000 cc.	Vol. (cc.) of air displaced by alcohol.	Percentage vol. of grain in one liter.	Vol. (cc.) of alcohol recovered.	Vol. (cc.) of alcohol lost.
1790	848.6	368.0	632.0	274	94.0
1802	848.6	365.4	634.6	281	84.4
1894	820.8	381.9	618.1	281	100.9
1817	858.9	360.6	639.4	272	88.6
1685	868.4	359.1	640.9	277	82.1
1645	883.0	358.7	641.3	277	81.7
1679	871.6	363.3	636.7	274	89.3
1687	896.3	361.0	639.0	292	69.0
1544	865.6	366.9	633.1	285	81.9
5192	841.6	374.8	625.2	277	97.8
Averages	860.3	366.0	634.0	279	87.0

From the ten cases above, it appears that on the average about 87 cc., or 0.087 liter, of alcohol was lost in each operation. A liter being 0.88 of a quart, the value of the alcohol lost, estimating the denatured alcohol at forty-four cents per gallon ($0.0968 per liter), the average cost of the alcohol lost in each operation would amount to $0.008, or 8 mills. This would be the cost where 95 per cent alcohol was used. A lower grade of alcohol can probably be used with equally satisfactory results. Experiments thus far made indicate that probably 70 per cent and possibly 50 per cent alcohol can be used.

In the practical use of commercial alcohol for determining the percentage volume of wheat in the proposed system of grading, a considerable portion of the alcohol lost in the grain could be recovered by distillation, provided it was found upon experiment to be profitable, as it probably would be in an important grain center, where a large aggregate volume of grading is done daily.

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Continued from second page of cover.

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MANHATTAN, KANSAS.

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EXPERIMENT STATION.—Bulletin 171.

ED. H. WEBSTER, *Director*.

TECHNICAL BULLETIN.

Bacteriological Department.

WALTER E. KING, *Bacteriologist in Charge*.

Studies on Hog Cholera and Preventive Treatment.

BY

WALTER E. KING, *Bacteriologist*.
ROBERT H. WILSON, *Assistant in Bacteriology*.

MANHATTAN, KAN.
SEPTEMBER, 1910.
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Studies on Hog Cholera and Preventive Treatment.

By

WALTER E. KING, Bacteriologist,
ROBT. H. WILSON, Assistant in Bacteriology.

INTRODUCTION.

In November, 1908, this department issued Bulletin No. 157, entitled "Studies on Hog Cholera and Preventive Treatment," in which were presented the results of the preliminary experiments relative to the work on "horse serum hog cholera vaccine." Since that time the work has been actively continued. The present bulletin, therefore, is written as a continuation of Bulletin No. 157, and while it presents the results obtained to date at this Station, it does not conclude the investigation.

Attempts are being made in this work to approach the problem from the following points of view:

1. The nature of the causative factor of hog cholera.
2. Methods of immunization.

While the use of hyperimmune serum, as developed according to the method employed by the Bureau of Animal Industry, United States Department of Agriculture, has passed far beyond the experimental stage and is, without doubt, of great value to the hog industry, yet the method has one serious disadvantage relative to the cost involved in its preparation. The success of the hyperimmune serum, as an effective preventive agent, is quite universally recognized, but the actual preparation and distribution of the product, at present, largely depends upon the various state legislatures. This fact alone tends to justify the statement that the cost of its preparation may seriously curtail its usefulness. Therefore, aside from the scientific interest pertaining to the subject of hog cholera, it appears important that aggressive work should be conducted relative to the many unsolved problems involved in the study of this animal disease. All honest and intelligent experimental efforts toward the solution of some of these problems constantly add to the knowledge the disease, and are therefore of practical significance.

PART I.

PREVENTIVE TREATMENT.

As a brief review of the experiments outlined in the preceding bulletin, it may be stated that the character of this experimental work involved the use of the horse as a medium in attempting to modify hog cholera virus. It was found that a short residence (one to two hours) of the hog cholera serum in the circulatory system of the horse did not change the infectious nature of the material. Indeed, experiments tended to show that a residence of one or two hours in the blood system of the horse sometimes apparently raised the virulence of the hog cholera virus. Experiments also showed that during a residence of from four to twenty-four hours in the circulatory system of the horse there was a gradual modification of the hog cholera virus, the degree of modification depending, as a rule, upon the number of hours allowed for this purpose. Theoretically, therefore, there seemed to be some period of time, at some point between four and twenty-four hours after the horse had received the intravenous injection of hog cholera serum, when the virus was sufficiently modified to act as a vaccine under all conditions, yet was devoid of infectious qualities.

The constant aim of the work for the past two years has been to collect experimental evidence bearing upon the above points. The chief emphasis has been placed upon the following attempted determinations:

1. To attempt to find after what period of residence in the horse, hog cholera virus becomes so modified (if a modification really does take place) that it may become an efficient vaccine. In other words, at what time after the horse is injected intravenously with approximately 150 cc. of hog cholera serum will the resulting horse serum produce a mild reaction, when injected subcutaneously into healthy hogs, and actively immunize, and at the same time possess no dangerous infectious qualities.

2. To study the possible virulent qualities of the horse serum drawn a relatively short time after the intravenous injection of the horse with hog cholera serum, and to determine, if possible, whether or not the horse serum virus is a mere dilution of hog cholera virus in normal horse blood.

3. To determine the approximate minimal fatal dose of highly virulent hog cholera serum.

4. To study the possibilities of hyperimmunizing hogs and producing protective hyperimmune serum by injecting immune hogs with the horse serum virus.

While no absolutely definite conclusions have been reached, on the whole the results have been fairly constant. It is recognized that some of the results lead us deeper into the jungle of unsolved questions, and emphasize the importance of repeated and persistent study in fields in which animal experimentation is involved. The statement should be made that one-half-hour horse serum virus (blood drawn one-half hour after the animal has received intravenously approximately 150 cc. of hog cholera serum) may not produce virulent hog cholera under all conditions when injected into healthy hogs. Neither may 24-hour horse serum (drawn twenty-four hours after the animal has received an injection of hog cholera virus) never produce symptoms of cholera. "The great variation among individual animals, and the peculiar idiosyncracies of swine particularly, preclude such a definite assertion."[1] It must be explained, therefore, that in attempting to verify the following experiments, one test or a few tests will not suffice. By those who are familiar with work of this nature, it is readily understood that only the average of a series of duplicate tests presents reliable results.

Field Work in 1908 with Experimental Horse Serum Hog Cholera Vaccine.

The results of a comparatively large number of duplicate tests at the Station indicate that 24-hour horse serum[2] possessed no pathogenic properties when injected into healthy hogs, but that it did contain enough modified hog cholera virus to impart to them some protective qualities. Moreover, it was quite definitely determined that the 24-hour horse serum was modified to such a degree that its vaccinating properties were not constant. A general survey of the whole work indicated that 24-hour horse serum might be used in the field with safety, but considerable doubt was entertained concerning its activity. The average of the results at the Station showed that the 24-hour horse serum might successfully protect from 15 to 45 per cent of the treated hogs. However, this was a point to be determined in the field, and accordingly several herds of healthy hogs were experimentally vaccinated with the serum.

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[1] Bulletin 157, Kansas State Eperiment Station, "Studies on Hog Cholera and Preventive Treatment," page 58.

[2] Hereafter in this bulletin the expression "½-hour horse serum," "6-hour horse serum," or "24-hour horse serum," will be used to indicate that the serum in question was obtained from the horse ½ hour, 6 hours or 24 hours after the animal had been injected intravenously with hog cholera serum.

The first test was made in a herd of 485 hogs, at Broughton, Kan. In this herd 222 pigs, weighing approximately 50 pounds each, received, individually, from one to five cubic centimeters of fresh 24-hour horse serum, 88 received Bruschettini's vaccine, and 175 were unvaccinated. Three weeks later this herd contracted hog cholera through natural exposure from an adjacent farm, and at the completion of the outbreak the following animals were dead: College vaccinated, 73.4 per cent; Bruschettini's vaccine treatment, 90 per cent; unvaccinated, 89.1 per cent. Thus it was found that in 222 susceptible pigs, situated under practical conditions, the 24-hour horse serum did not produce even a noticable reaction, and furthermore that the serum was modified to such a degree that it protected only 15.7 per cent of the treated animals.

Three other small herds of hogs in the field, consisting of a total of 28 treated animals, were vaccinated with 24-hour horse serum. In none of these herds did the vaccinated hogs show any disturbances, nor did any of the three herds subsequently become infected through natural exposure.

In the meantime, a number of preliminary duplicate tests with 6-hour horse serum, both at the Station and in the field, appeared to warrant an extensive field test with that experimental product. In these preliminary tests, including the treatment of a relatively large number of hogs with small subcutaneous injections of 6-hour horse serum, no serious symptoms had occurred. It was also made evident by careful test that the protection following the use of the 6-hour horse serum was greater than that resulting from the treatment with the 24-hour horse serum. During the months of October, November and December of 1908, and January of 1909, a total of 809 hogs in twenty-eight different herds[3] were experimentally vaccinated with 6-hour horse serum vaccine.[4] These hogs, with the exception of one herd, were situated on various farms in the state of Kansas. Among the twenty-eight treated herds 612 unvaccinated, or control hogs were kept in the same enclosures with the vaccinated animals, under the same practical conditions.

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[3] Four other herds, making a total of 82, were treated during the spring months of 1909 with 6-hour horse serum. From these no reports were sent in, and they are therefore not included.

In eleven of these herds the experimental 6-hour horse serum vaccine appeared to produce the disease. In some of these instances the disease appeared in a mild form, but in several

TABLE 1. Results of field work with experimental horse serum vaccine.
Twenty-four-hour horse serum.

HERD.	No. vaccinated.	No. vaccinated died.	Per cent.	No. of controls.	No. of controls died.	Per cent.
1	222	163	73.44	175	157	89.71
2	4			6		
3	14			9		
4	7			5		
Total	247	163	65.99	195	157	80.51
Six-hour horse serum.						
5	125	25	20.00	140	126	90
6	4			3		
7	32	13	40.62	26	1	3.84
8	55	7	13.63	9	3	33.33
9	25	2	8	2	0	0
10	43	25	58.13	2	0	0
11	18	9	50	54	15	27.77
12	18	12	66.66	3	3	100
13	6	5	83.33	2	2	100
14	28	4	14.28	36	7	19.44
15	77	17	22.07	49	14	28.57
16	39	3	7.69	10	4	40
17	10	8	80	10	4	40
18	13	8	61.53	1	1	100
19	9	1	11.11	7	0	0
20	3			3		
21	6	6	100			
22	25	16	64	20	20	100
23	27	2	7.40	47	0	0
24	41	41	100	5	0	0
25	13	9	69.23	9	7	77.77
26	7	4	57.14	7	5	71.42
27	11			11		
28	42	3	7.14	3	0	0
29	11	10	90.98	11	11	100
30	65	29	44.64			
31	20	1	5	6	0	0
32	36			2		
Totals	809	260	32.13	478	223	46.65

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[4] The Station is indebted to Dr. Charles T. McClintock, director of the Department of Experimental Medicine, Parke, Davis & Co., Detroit, Mich., for the services of his assistant, Dr. R. L. Rhea, in conducting the greater part of this field work.

cases acute hog cholera was present. Of the total of vaccinated hogs, 7.1 per cent gave evidence of contracting the disease from the vaccine. With almost no exceptions these were corn-fed hogs which were being fattened for market. Nearly all of these eleven herds were in close proximity to hog cholera at the time of vaccination; therefore, in some cases the disease may have gained access before the time of treatment.

Herd No. 28 (table 1), situated at Jewell City, Kan., was vaccinated on November 27, 1908. Forty-two of these hogs, weighing about 225 pounds per head, each received subcutaneously 5½ cc. of 6-hour horse serum vaccine. In this herd a severe reaction followed the vaccination. Six of the treated animals became sick and 3 died in a few days. The other 3 recovered soon after the signs of the reaction disappeared in the remainder of the 42 treated animals. During this experiment, hog cholera existed in a neighboring herd within about sixty rods of the vaccinated animals; however, after the results from vaccination had occurred these hogs remained in a normal condition.

In eleven of the total twenty-eight herds, hog cholera apparently existed at the time of vaccination. In these herds an average of about 45 per cent of the vaccinated hogs and from 55 to 60 per cent of the unvaccinated animals ultimately succumbed to the disease.

In herd No. 14 (table 1), located at Frankfort, Kan., 28 hogs were vaccinated and 36 were left as controls. A few animals in this herd were evidently infected by natural exposure previous to the time of vaccination. On the next day after treatment 2 of the vaccinated hogs were sick, and on the second day after, 2 additional animals. On the third day these 4 treated animals died. The injection of the modified virus evidently accelerated the disease. None of the remaining 24 vaccinated hogs showed the slightest symptoms of the disease, while over 50 per cent of the 38 controls became sick and 19.4 per cent died. Lung lesions were prominent in this outbreak. Excluding the 4 animals which died three days after vaccination, 100 per cent of the treated animals in this herd were saved. These hogs were lightly fed, before and after vaccination, on alfalfa and small rations of corn.

On December 24, 1908, herd No. 5 (table 1), consisting of 268 hogs, near Dallas, Tex., showed symptoms of hog cholera.

During that morning 3 of the animals died, and on that day 125 of the hogs were vaccinated with 6-hour horse serum vaccine; and 140 were left unvaccinated. By the latter part of February, 1909, the disease had evidently run its course and only 20 per cent of the vaccinated hogs were dead, while 90 per cent of the controls had succumbed. This herd was fed hotel refuse and received very little heavy diet such as corn.

Table 1 shows the average result of the field work with the experimental horse serum vaccine. By placing all of the results together, without regard to different conditions to which references are made above, it is found that death from hog cholera resulted in 32.13 per cent of the hogs treated with 6-hour horse serum vaccine, as against 46.65 per cent of the untreated animals.

From an experimental point of view these results were satisfactory. Individual losses occurred to a few of the farmers who volunteered to coöperate with the Station in this work. Such losses have occurred because the Station had insufficient means to carry on extensive experiments in this line of investigation without such coöperation. Perhaps it should be stated that those farmers who coöperated in this work did so voluntarily after clearly understanding the nature of the investigation. While no specific contract existed between the individual farmer and the Station, yet in every single instance the experimental nature of the work was carefully explained through correspondence. By virtue of this, the Station was not responsible, either legally or morally, for individual losses which occurred.

The results of the field work may be summed up as follows:

1. Twenty-four-hour horse serum vaccine, as a rule, is lacking in infectious properties. It possesses some degree of protection, which, however, is not constant enough to prove of practical use.

2. Six-hour horse serum vaccine, under certain conditions relative to character of diet and individual variation in susceptibility, produces virulent hog cholera. It possesses greater protective properties than does 24-hour horse serum vaccine, and under certain conditions in the field it may save from 80 to 100 per cent of the treated animals. For practical field conditions, however, 6-hour horse serum vaccine is not safe.

3. After the intravenous injection of the horse with ap-

proximately 150 cc. of hog cholera virus, the virus becomes modified, the degree of modification depending, as a rule, upon the period of residence in the circulatory system of the horse. It is possible that 10- to 15-hour horse serum vaccine might possess both safety and activity.

4. In addition to the observations of various investigators and the common knowledge of those familiar with hog cholera, a general survey of the field work in this investigation emphasizes the following conditions:

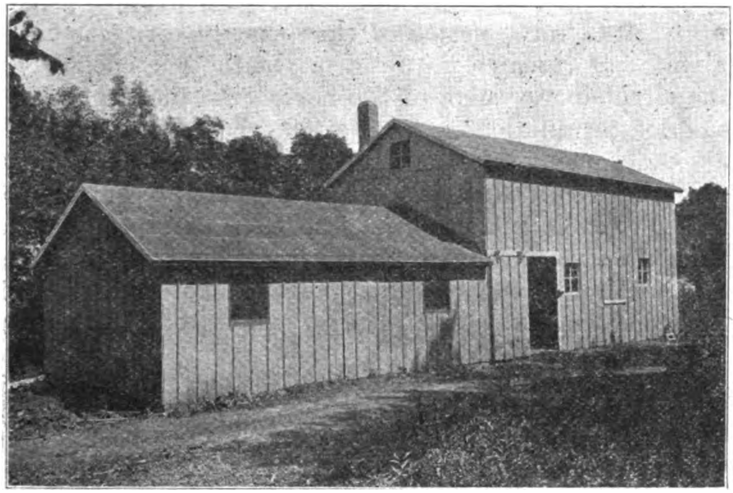
(*a*) That the character of the diet has great influence upon susceptibility and resistance to the disease, heavy rations of corn being especially conducive to increased susceptibility.

(*b*) That, while hog cholera is usually much more prevalent during the fall months, hogs are easily infected in cold weather.

(*c*) That lung lesions may predominate in one locality while intestinal lesions may be more frequent in another locality.

Infectious Nature of Horse Serum Virus.

After the completion of the field work, it became necessary to study the nature of the hog cholera virus when modified by passage through the horse. Among the points which demanded careful attention, it was especially important that some tests should be made to show whether or not horse serum virus is a mere dilution of hog cholera virus. Therefore, in addition to the suggestive data already obtained, it was deemed advisable to make a series of duplicate tests upon susceptible pigs with horse serum drawn at varying intervals of time, representing short periods of residence after the horse had received intravenous injections of hog cholera virus. To determine, if possible, whether or not the horse serum so treated represented nothing other than a dilution of the original hog cholera serum, plans were made to estimate the approximate dilution of virus when the virus was injected into the blood of the living horse, and compare the results from the injection of this into susceptible pigs, with the corresponding dilutions of the same virus in normal horse blood outside the body of the animal, and in sterile physiological salt solution. It was necessary, therefore, in each series of experiments to weigh the horse under observation, estimate the amount of blood contained in his body by taking one-fifteenth of the body weight, then compute the dilution of hog cholera serum *in vivo*, when



Pate I. Exterior of experimental stable, including hog wards, laboratory and horse stable.

the animal received intravenously a given quantity of the virus. When the blood was drawn from the horse from a half to nine hours after injection of the virus, the resulting horse serum was tested as to its infectious properties by injecting it subcutaneously into susceptible pigs, using an approximate dosage of 4 cc. of the horse serum per 50 lbs. weight. In each case, duplicate tests were made of the same lot of hog cholera virus, placed in the same dilution in normal, citrated or defibrinated horse blood, immediately after drawing, and in ster-

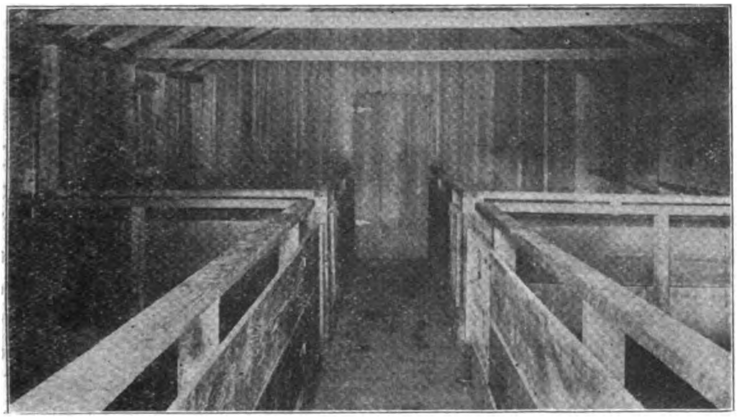


Plate II. Interior of experimental stable, showing hog wards.

ile, physiological salt solution, both being kept at a temperature of 37° C. for a period of time exactly corresponding to that which represented the residence of the hog cholera virus in the circulatory system of the horse. At the expiration of this period the dilutions were injected subcutaneously into susceptible pigs, using the same rate of dosage as in the case of the horse serum virus. In this work all possible precautions were exercised to avoid extraneous exposure. At first, the temperatures of the experimental animals were taken from the date of inoculation until the test was completed. Later this was discontinued, owing to possibilities of exposure to the disease.

PLATE III. Interior of experimental stable, showing laboratory containing bleeding table and horse stocks.

These test pigs were kept in the experimental stable, each individual test, of course, being confined to an isolated pen. The pens were provided with cement floors and with continuous three-foot sides of cement. Each pen was separated from the others by a two-foot cement alley. As a control for these experiments, a susceptible 50-pound pig was kept in one of these pens for several months during the investigation. This animal remained in a normal condition throughout. In order to determine whether or not it was protected by natural immunity, it was later placed with hogs suffering from hog cholera. This control animal promptly showed symptoms of the disease about five days after the natural exposure, thus indicating that it successfully served as a check during the experimental work.

TABLE 2. Treatment of experimental horses.

No.	No. of bleeding.	Wt. lbs.	Date of injection.	Amt. of virus injected.	Approximate dilution of virus.	Period of residence of virus in horse.	Lot of serum.
1	1st bleeding...	1,150	12 30, 1909	100 cc.	1 to 344.7...	½, 1, 2, 3½ and 9 hours,	A
1	2d " ...	1,150	2 12, 1910	100	1 to 344.7...	½ and 9 hours	B
2	1st " ...	800	3 14, 1910	100	1 to 240.3...	½ hour	C
1	3d " ...	1,150	4 4, 1910	120	1 to 287.2...	½ hour	D
2	2d " ...	800	5 7, 1910	140	1 to 171.7...	½ hour	E
1	4th " ...	1,150	5 20, 1910	40	1 to 861.8...	½ and 1 hour	F
3	1st " ...	1,050	5 24, 1910	130	1 to 244.2...	½ hour	G
2	3d " ...	800	7 2, 1910	20	1 to 1202.....	½ hour	H
1	5th " ...	1,150	7 11, 1910	20	1 to 1724.....	½ hour	I

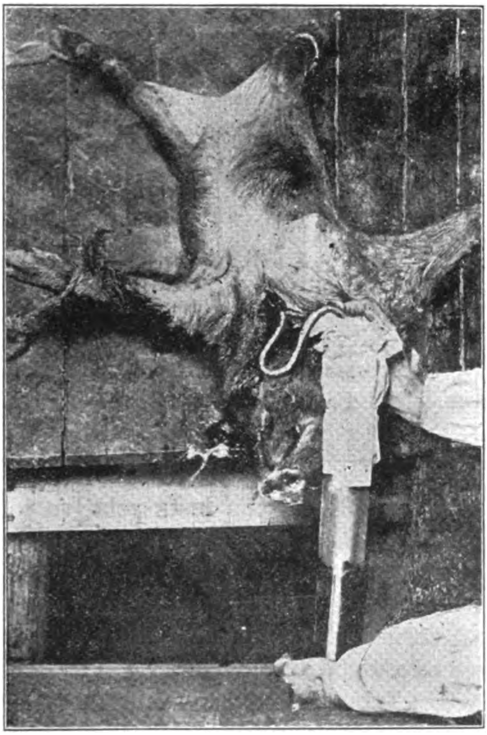


PLATE IV. Bleeding hog aseptically from carotid artery. Bleeding table inclined at an angle of about 45 degrees.

Table 2 shows the general data relative to the use of the experimental horses. Three animals were used, a detailed description of which will be found in part II of this bulletin. In each case the horse was injected aseptically in the jugular vein with hog cholera serum. The hog cholera serum was drawn aseptically from the carotid artery of moribund hogs at some period less than fifteen days after subcutaneous inoculation with hog cholera virus, and was examined bacteriologically before being injected into the horse. After the intervals of time indicated in table 2, a quantity of blood was drawn aseptically from the jugular vein of the horse into sterile cylinders, and the serum allowed to separate from the clot.

TABLE 2*a*. Tests of horse serum virus.

MATERIAL INJECTED.	Hog.	Date, 1910.	Incubation period.	Results.	Autopsy.
A. ½-hr. horse serum...	61	1 4	5 days.	Died in 11 days............	Typical lesions.
A. do. do.	64	1 11	5 "	" 11 "	do. do.
A. do. do.	71	2 8	....	Remained well. Immune.	
B. do. do.	72	2 19	6 days.	Died in 13 days............	Typical lesions.
B. do. do.	73	2 19	7 "	Severe reaction, rec.	
C. do. do.	87	3 18	5 "	Died in 13 days............	Typical lesions.
C. do. do.	88	3 18	5 "	" 27 "	do. do.
D. do. do.	94	4 5	7 "	" 13 "	do. do.
D. do. do.	95	4 5	6 "	" 13 "	Slight lesions.
E. do. do.	107	5 11	8 "	" 13 "	do. do.
F. do. do.	109	5 21	6 "	" 9 "	Typical lesions.
G. do. do.	126	6 18	10 "	" 19 "	do. do.
G. do. do.	133	6 28	12 "	" 19 "	do. do.
H. do. do.	135	7 2	14 "	Chronic case, rec.	
I. do. do.	137	7 11	....	No reaction.	
A. 1-hr. horse serum....	63	1 4	6 days.	Severe reaction, rec.	
A. do. do.	110	5 21	7 "	Died in 10 days............	Slight lesions.
A. 2-hr. horse serum....	62	1 4	7 days.	Severe reaction, rec.	
B. do. do.	66	1 20	8 "	Died in 24 days............	Typical lesions.
A. 3½-hr. horse serum..	67	2 3	12 days.	Died in 20 days.....	Fair lesions.
A. 9-hr. horse serum....	65	1 20	8 days.	Died in 33 days............	Typical lesions.
B. do. do.	74	2 19	8 "	" 24 "	do. do.

Table 2*a* shows results of the tests relative to the virulent properties of the horse serum, drawn at varying intervals after the injection of the animal with hog cholera virus. A dosage of approximately 4 cc. per 50 lbs. weight was used in all cases. Corresponding series of tests representing the same lot of original hog cholera virus are characterized by the same letters, A, B, C, etc. The temperature curves of hogs 64, 71, 72, 73, 87 and 88 are shown in tables 4 to 9. With the exception of hog 71, which was evidently naturally immune, the thermal reactions, as a rule, indicated temperatures which are characteristic

of the acute form of hog cholera. The temperature curves of hogs 62, 63, 65, 66, 67 and 74, injected respectively with 2-hour, 1-hour, 9-hour, 2-hour, 3½-hour and 9-hour horse serum are shown in appended tables 10-15. A general comparison of these temperature reactions with those of hogs 64, 71, 72, 73, 87 and 88 indicates the presence of the chronic form of the disease.

Hog 61, Duroc-Jersey shoat, weight 40 pounds, was inoculated subcutaneously January 4 with 4 cc. of ½-hour horse serum, the horse having received 100 cc. of hog cholera virus. The hog appeared normal until the seventh day, when it became "off feed" and symptoms of cholera appeared. Vomition, dyspnœa, cough, inflamed rectum, swollen eyelids, emaciation, etc., showed in the train of symptoms. The temperature fluctuated considerably, its highest point being 106.5 degrees on the twelfth day. On this day, the animal being moribund, it was anæsthetized and bled aseptically from carotid artery. About 400 cc. of blood were obtained.

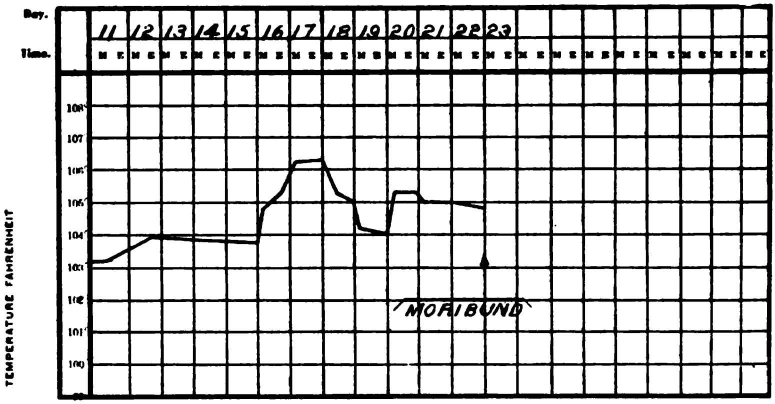
Post mortem. Cutaneous lesions not pronounced. Intestines showed inflammation throughout their length. A few small ulcers were visible around the ileocæcal valve. Mesenteric glands enlarged and hemorrhagic. Spleen enlarged and pulpy. Kidneys covered with petechiæ. Lungs hepatized at apices and showing congestion in other parts. Auricles hemorrhagic. Mediastinal glands congested.

Hog 64. This pig was a male Duroc-Jersey, weight about 40 pounds. On January 11 was inoculated subcutaneously with 4 cc. of ½-hour horse serum, the same amount and quality of virus with which hog 61 was inoculated, in order to confirm the results obtained in test 61. On the sixth day there was rise in temperature, which reached its maximum on the eighth day. On this day the pig became "off feed." Other symptoms, such as coughing, dyspnœa, constipation, later diarrhea, and great emaciation, were evident. The pig, being moribund the twelfth day, was bled and post-mortemed.

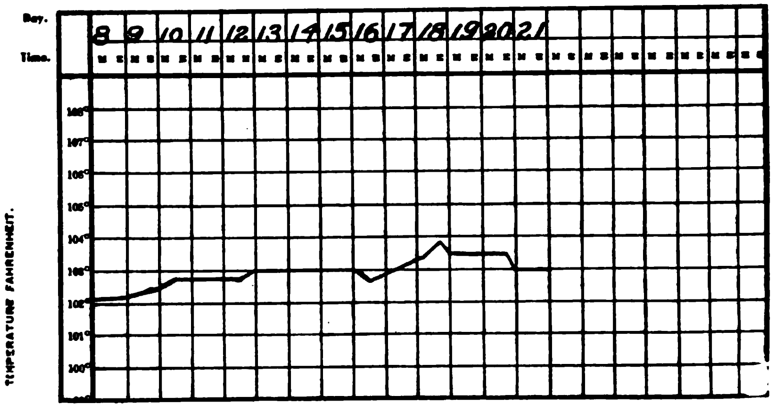
Post mortem. A few blood extravasations were visible under skin in ventral portion of body. Considerable enteritis was present, but no ulcers in vicinity of ileocæcal valve. Spleen enlarged and covered with reddish velvety villi. Kidneys apparently normal. Several small necrotic ulcers in liver. Mesenteric glands enlarged and hemorrhagic. Lungs showed the results of a severe inflammation. Some parts congested, other hepatized. Hepatization was more pronounced in the apices. Mediastinal glands enlarged and almost black in color. Auricles hemorrhagic.

Hog 72, weight 50 pounds, was inoculated subcutaneously February 19 with 4 cc. of ½-hour horse serum. On the ninth day after inoculation hyperthermia was noticed, and on the succeeding day the temperature rose to 107.4 degrees and remained near this point until the last. Symptoms of cholera were conspicuous on the tenth day. Accompanying the high temperature were anorexia, diarrhea, dyspnœa, sticky mucous discharge from eyes, and inflamed rectum. The animal rapidly emaciated.

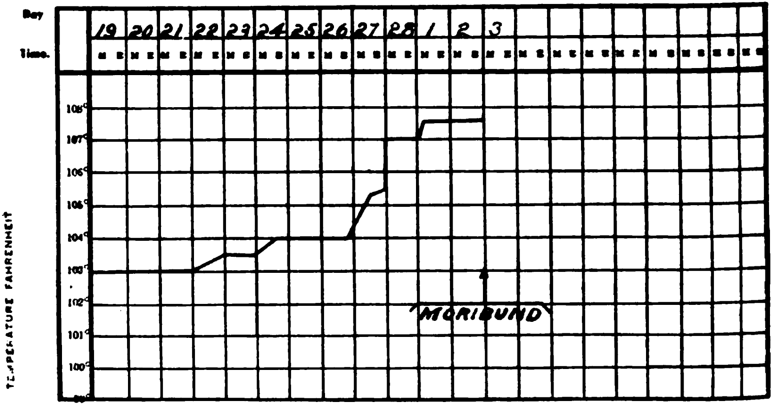
Year and Month. JAN. 1910 — HOG 64. — TABLE 4.



Year and Month. FEB, 1910. — HOG 71. — TABLE 5.



Year and Month. FEB, 1910 — HOG 72. — TABLE 6.



A decubitus was maintained after the tenth day, the animal occasionally getting up to drink. On the twelfth day, the hog being moribund, it was anæsthetized and bled aseptically from the right carotid artery.

Post mortem. No cutaneous lesions were visible. An enteritis was present in the large intestine, especially the cæcum. A few small undeveloped ulcers were present near the ileocæcal valve. The mesenteric glands were slightly involved, being somewhat enlarged and hemorrhagic. Spleen practically normal in size, but very dark and friable. Liver apparently normal. Kidneys showed numerous petechiæ on surface, and on section showed congestion and inflammation. Lungs normal, both in color and consistency. Auricles of heart thickly studded with hemorrhagic foci. Mediastinal lymph glands black in color and very hard.

Hog 87, a 30-pound Yorkshire, received, March 18, 4 cc. of ½-hour horse serum. Several days after receiving this serum, hyperthermia was noticeable, followed later by anorexia, dyspnœa, and vomition. These symptoms became intensified. The animal, being moribund on the fourteenth day, was bled and post-mortemed.

Post mortem. Pinkish discoloration of the skin on abdomen. A slight inflammatory condition in vicinity of ileocæcal valve, remainder of intestines practically normal. Lungs showed hemorrhagic foci; some hepatization at apices. Auricles of heart ecchymotic.

Hog 88, a Duroc-Jersey, weight 45 pounds, injected March 18 with 4 cc. of ½-hour horse serum. Five days after injection hog refused feed and showed symptoms of cholera. Bled and post-mortemed April 14.

Post mortem. Cutaneous lesions absent. Intestines inflamed; a button-shaped ulcer in cæcum. Kidneys petechiated. Liver normal. Spleen enlarged and hemorrhagic. Lungs hepatized and ecchymotic. Mediastinal glands enlarged and dark in color.

Hog 94, Duroc-Jersey, weight 40 pounds, received 4 cc. of ½-hour horse serum. Animal refused feed on ninth day and showed a general depression. Gradually became worse, and died April 18.

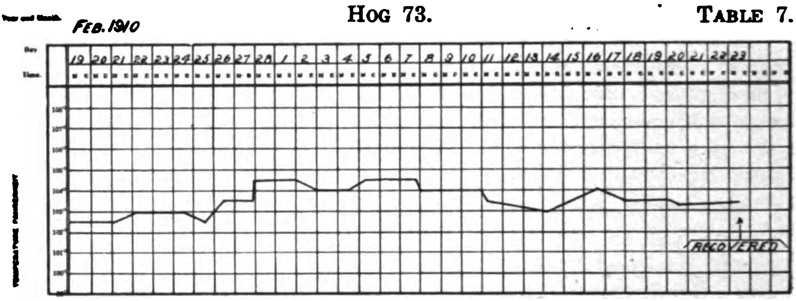
Post mortem. Skin on abdomen and inner side of thighs reddish purple in color. Considerable enteritis present. A few small ulcers at junction of ileum and cæcum. Kidneys thickly studded with petechiæ. Spleen enlarged, black and pulpy. Liver apparently normal. Mesenteric glands enlarged and hemorrhagic. Mucosa of stomach inflamed, especially that of pyloric portion. Lungs covered with large hemorrhages, apices of lungs hepatized. Auricles hemorrhagic. Mediastinal glands enlarged and hemorrhagic.

Hog 95. This test was a duplicate of that upon hog 94. Incubation period, symptoms and lesions identical with those of 94.

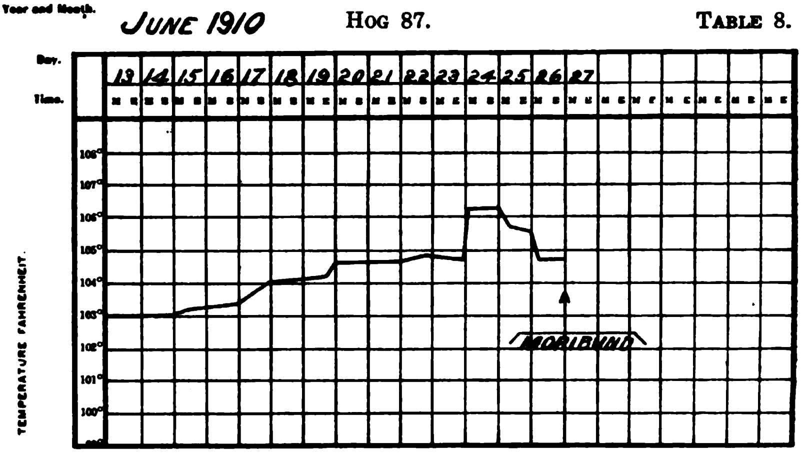
Hog 107, Duroc-Jersey, weight 70 pounds, was injected May 11 with 4 cc. of ½-hour horse serum. Sickened the eighth day, showing symptoms of cholera. Was bled May 24, thirteen days after injection.

Post mortem. Slight cutaneous lesions. Intestines normal, with the exception of a small area near ileocæcal valve, which was inflamed. Spleen enlarged and friable. Liver practically normal. Kidneys slightly

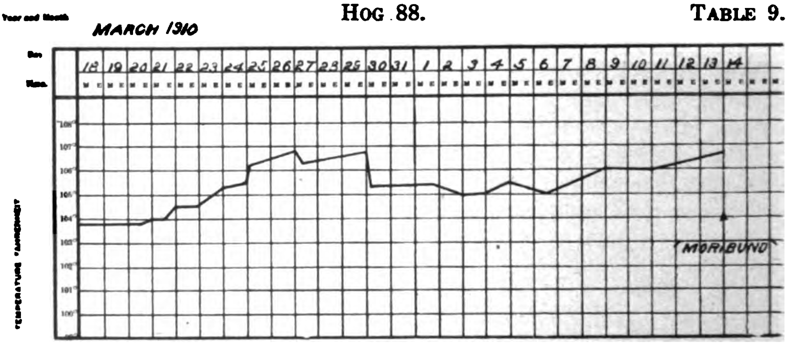
Hog 73. Table 7.



Hog 87. Table 8.



Hog 88. Table 9.



petechiated. Lungs showed the results of a severe inflammation, being hemorrhagic and hepatized in many places.

Hog 109, Duroc-Jersey shoat, weight 90 pounds, on May 21, 1910, received 4 cc. of ½-hour horse serum, the horse having received 40 cc. of hog cholera virus intra-jugular and bled one-half hour after injection. Incubation period, six days. Symptoms and lesions typical of hog cholera, although the lesions not as pronounced as usual. This hog received approximately $\frac{1}{225}$ of a cc.

Hog 126, Yorkshire, weight 60 pounds, injected with 4 cc. of ½-hour horse serum, on June 18. Ten days after injection feed was refused and animal appeared listless. Other symptoms appeared, such as dyspnœa, great thirst, constipation, later diarrhea and emaciation. Died during night of July 7.

Post mortem. Lesions typical of cholera.

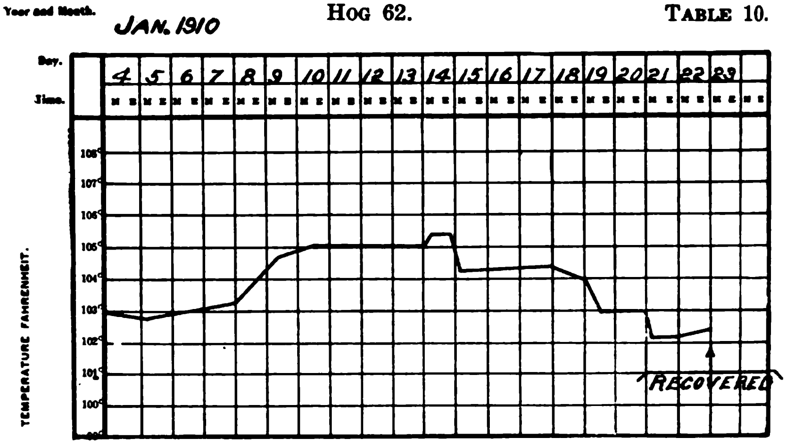
Hog 133, Duroc-Jersey, weight 50 pounds, injected June 28 with 4 cc. of ½-hour horse serum. Sickened on the twelfth day. Symptoms characteristic of cholera. Died July 17.

Post mortem. Skin on ventral portion of body purplish in color. Intestines inflamed and dotted with hemorrhagic foci. A few small undeveloped ulcers near ileocæcal valve. Mesenteric glands enlarged and gorged with blood. Kidneys petechiated. Liver contained several necrotic areas. Spleen pulpy and very dark. Numerous blood extravasations in lungs. Auricles ecchymotic. Mediastinal glands involved.

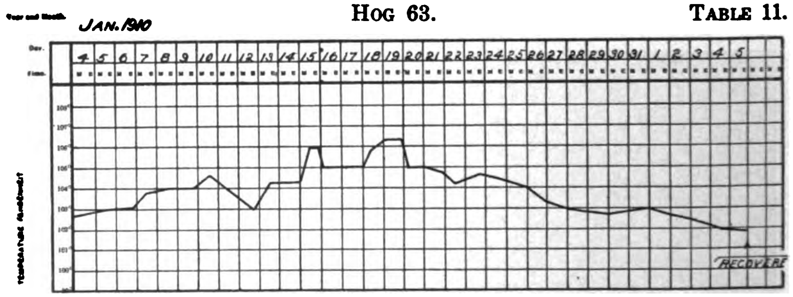
Hog 65, a Poland China, weight 65 pounds, was inoculated subcutaneously with 5 cc. of 9-hour horse serum, on January 20, 1910. The hog was apparently healthy until the thirteenth day, when it gradually went off feed and took on a listless appearance. The temperature fluctuated considerably between normal, 103.5 degrees, and 106 degrees. Would have chills, usually one or two a day, lasting about an hour at a time. Had a severe cough. At times the animal would seem to be improving, leaving its bed and walking around the pen; would also stand at the feed trough with the other hogs and eat ravenously. These periods of seeming convalescence would not last long, however, the pig returning to its bed and resuming its usual decubitus and appearance. The patient lingered along in this condition for over thirty days, before dying. Towards the end it experienced great difficulty in breathing, every breath seeming to be painful. The feces appeared to be normal throughout the course of the disease.

Post mortem. A slight discoloration of the skin was noticeable on the ventral portion of the body and on the inner side of the thighs. The intestines were practically normal, a slight inflammation being present around the ileocæcal valve. The contents of the intestines appeared to be normal in consistency and color. Mesenteric glands but slightly involved. Spleen and liver practically normal. Kidneys slightly ecchymotic near pelvis. The thoracic cavity was the seat of very pronounced lesions. The lungs were practically one solid mass of hepatized, necrotic tissue. Upon section with a bistoury, a fatty, cheesy-like appearance was revealed. In interstices between the lungs and pleura, when they

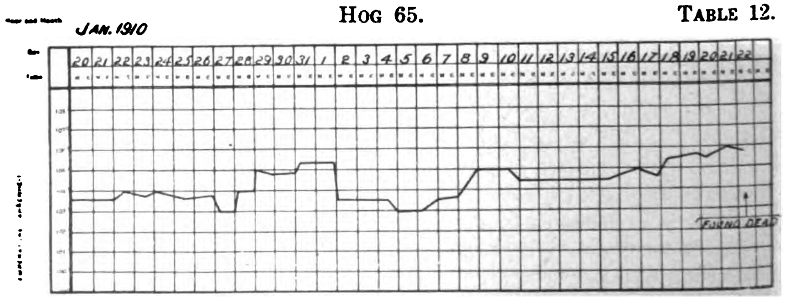
HOG 62. TABLE 10.



HOG 63. TABLE 11.



HOG 65. TABLE 12.



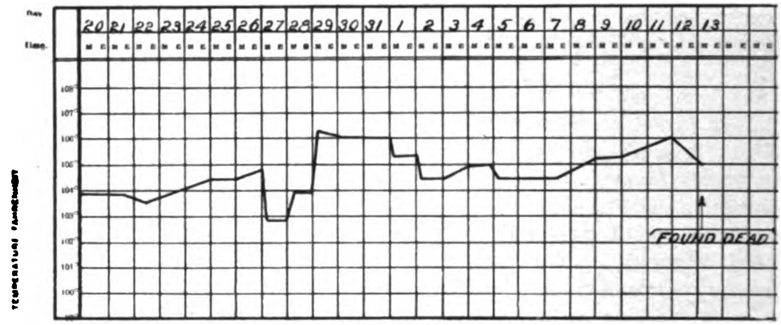
were not adherent, was present a clear jelly-like liquid, partly organized in places. Probably not more than one-fifth of the total lung tissue was functional, this undoubtedly accounting for the dyspnœa and other grave respiratory troubles which the animal experienced. The pericardial fluid was almost solidified, encasing the heart in a mold. Auricles very dark in color and hemorrhagic. Mediastinal glands slightly enlarged and showing blood extravasations.

Hog 66, A Poland China sow, weight 85 pounds, was inoculated subcutaneously January 20 with 5 cc. 2-hour horse serum. The normal temperature was 103.8 degrees. The temperature remained normal after inoculation until the sixth day, when it rose to 104.5 degrees, and dropped to 102.8 degrees on the 8th day. The highest mark recorded in the temperature chart was on the tenth day, when the temperature was 106.5 degrees, fluctuating between this point and normal until the death of the animal. The animal refused feed on the tenth day and showed other signs of illness. Probably the most pronounced symptom in the early stage, aside from being "off feed," was a dry hacking cough. The coat became rough and staring, eyes congested and swollen. It was almost impossible for it to move from its bed. Limbs cold, the posterior ones seeming to be partially paralyzed. The animal lingered along, gradually becoming weaker, until the twenty-fourth day after inoculation, when it died.

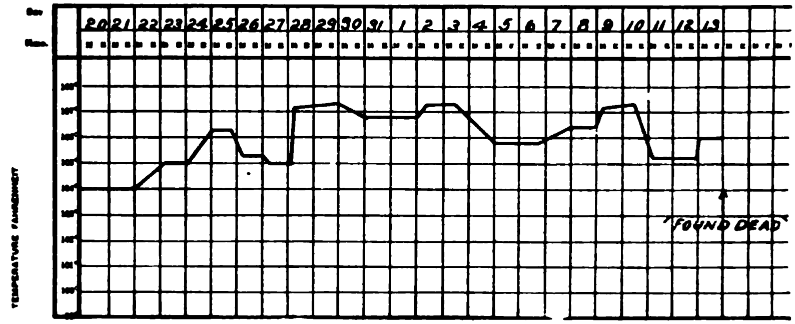
Post mortem. The autopsy was not held until two days after death, but the weather being very cold, the cadaver was preserved in good condition. The body was not badly emaciated, in spite of the fact that the animal had not eaten for nearly two weeks previous to death. The skin on the ears was slightly discolored, being a purplish hue. The intestinal walls showed hemorrhagic foci in places. No ulceration was visible in the cæcum, nor at the ileocæcal valve. The mesenteric glands were almost black in color and greatly enlarged. Spleen normal in size and color, but very soft and friable. Kidneys showed petechtiæ, the petechiation being more pronounced in the hilus of the organ. Liver showed a few ulcerative, necrotic areas. Extensive lesions were found in the lungs, the lower portions of the lobes being in the stage of gray hepatization, the consistency being almost solid; other portions showing the results of various stages of inflammation. Evidence of severe pleuritis was noticeable, the lungs being adherent to pleura in places. The heart showed petechiæ, the petechiæ being more extensive in the auricles. Mediastinal glands enlarged and hemorrhagic. A striking feature in this case was the extent of the glandular involvement—every set of glands from the retropharyngeal to the inguinal showed affection.

Hog 67 was a Poland China male, in good thrifty condition, weighing 95 pounds. On January 20 was inoculated subcutaneously with 6 cc. of 3½-hour horse serum. On the morning of the ninth day the animal missed its first feed, and gave a temperature of 107 degrees. It maintained this degree of temperature almost throughout the course of the disease. The animal would lie in its bed almost continuously, occasionally getting up to drink. Gave evidence of great thirst, naturally arising from the high

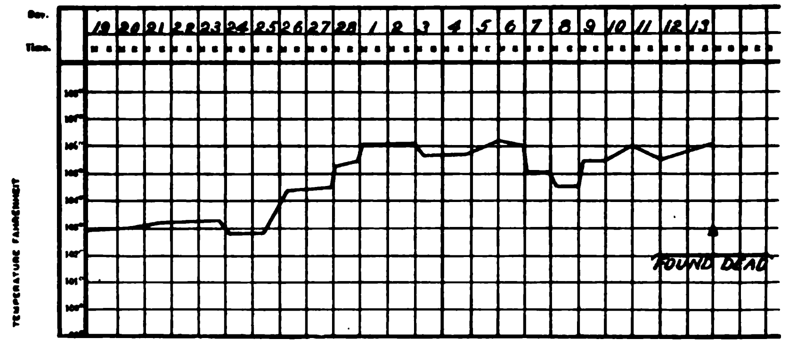
Hog 66. Table 13.



Hog 67. Table 14.



Hog 74. Table 15.



fever. Had a very severe cough, almost going into convulsions at times. Eyes became dull and listless, coat rough and staring, had a watery mucous discharge from rectum. The animal did not seem to convalesce or to get worse until the twenty-third day, when the symptoms became aggravated, and the patient rapidly weakened, finally succumbing the night of February 13, twenty-five days after inoculation.

Post mortem. Did not show any cutaneous lesions. Intestines slightly inflamed in region of cæcum, but no ulcerations. Mesenteric glands involved. Spleen normal in size, but dark and soft. Liver normal. Mucosa of stomach inflamed and pyloric portion covered with a diphtheretic-like membrane. Kidneys showed petechiæ on surface. Apices of lungs hepatized and base of right lung congested and inflamed. Lungs adherent to pleura in places. Chambers of heart gorged with black, jelly-like clots. Auricles ecchymotic. Mediastinal lymph nodes enlarged and hemorrhagic.

Hog 74, a Poland China male, weight 50 pounds, received subcutaneously, February 19, 4 cc. of 9-hour horse serum. On the eighth day after injection it had a rise in temperature of two degrees. On the eleventh day the temperature was 106 degrees and the hog showed signs of illness—loss of appetite, dyspnœa, constipation and a marked general depression. Later diarrhea appeared, the feces being very watery and tinged with blood. The hog rapidly emaciated and weakened, dying the night of March 14, 1910.

Post mortem. No cutaneous lesions. Spleen practically normal. Intestines inflamed, more particularly the small intestines. Kidneys showed hemorrhagic foci. Liver studded with numerous small necrotic centers, which on section were found to contain thick caseous pus. Lungs were pneumonic in appearance, more especially the left lung. Pericardial fluid almost solidified. Auricles hemorrhagic. Mediastinal and bronchial glands showed involvement, being enlarged and hemorrhagic.

Hog 110, Duroc-Jersey shoat, weight 85 pounds, received, May 21, 4 cc. of 1-hour horse serum. Incubation period six days. Symptoms and lesions characteristic of hog cholera.

From the above tests it may be observed that ½-hour horse serum, as a rule, is highly infectious in nature. With the exception of natural immune No. 71, a subcutaneous injection of 4 cc. per 50 pounds weight produced in a series of twelve pigs (hogs 61, 64, 72, 73, 87, 88, 94, 95, 107, 109, 126 and 133) acute cholera, with an average incubation period of 6.8 days and an average termination of the disease in 14.8 days, of 91.6 per cent of the cases, hog 73 having recovered. On the whole, from the limited observations afforded by the experiments with 1- to 9-hour horse serum, as indicated in table 2*a*, previous results were verified.

TABLE 16. Tests of normal horse blood dilution *in vitro*.

MATERIAL INJECTED.	Hog.	Date, 1910.	Incubation period.	Results.	Autopsy.
A. ½-hr. dilution in normal horse blood....	68	2 8	12 days.	Died in 20 days	Slight lesions.
A. do. do.	69	2 5	14 "	Slight reaction, rec.	
B. do. do.	79	3 8	8 "	do. do.	
B. do. do.	80	3 8	9 "	Died in 15 days (not hog cholera)...............	No cholera lesions.
C. do. do.	99	4 15	9 "	Slight reaction, rec.	
C. do. do.	100	4 15	10 "	Died in 17 days..........	No cholera lesions.
E. do. do.	113	5 27	....	No reaction.	
F. do. do.	132	6 23	18 days.	Died in 21 days..........	Slight lesions.
G. do. do.	134	6 30	....	No reaction.	
H. do. do.	141	7 20	....	do.	
I. do. do.	140	7 20	....	do.	

Hog 68, weight 65 pounds, received in the subcutem 4 cc. of a mixture of normal horse blood and hog cholera virus. One per cent sodium citrate was added to the blood immediately upon drawing from the horse, to prevent coagulation. The mixture was kept at a temperature of 37 degrees C. for one-half hour before injection. The animal was apparently normal until the twelfth day, when it refused feed. Other symptoms gradually appeared, such as hyperthermia, constipation, followed by diarrhea, dyspnœa, coughing, gummed eyelids, and a general debility. The animal died the twenty-first day after injection.

Post mortem. The intestinal tract showed evidence of inflammation, more particularly the stomach, the mucosa of which was badly congested and inflamed. No intestinal ulcers were present. Right kidney slightly ecchymotic near hilus. Spleen and liver practically normal. Lower portions of lungs badly hepatized. Some pleuritis. Heart muscle hemorrhagic.

Hog 80, a 30-pound Yorkshire shoat, received on March 8 3½ cc. of ½-hour dilution (1 cc. hog cholera virus and 350 cc. horse serum). Thirteen days after injection the animal seemed to be suffering from a paraplegia, at times being unable to rise without assistance. Had considerable fever and appeared to be greatly depressed. No typical symptoms of cholera were in evidence. The hog was bled March 23, 1910.

Post mortem. The only apparent pathological condition was a great distention of the bladder, the animal apparently not having urinated for several days. The bladder occupied the greater portion of the pelvic cavity and extended well into the abdominal cavity. The pressure exerted by the distended bladder on the surrounding nerves was probably the cause of the paralysis of the hind parts. All the other viscera seemed to be normal.

Hog 100, a Duroc-Jersey, weight 50 pounds, received on April 15 4 cc. of a mixture of horse blood and hog cholera virus (1 cc. virus and 240 cc. blood). Ten days after injection feed was refused and animal became listless. A profuse, watery diarrhea occurred the twelfth day and continued until the end. Would lie in a corner of the pen continually, seeming to be semiconscious. Animal weakened gradually, and died May 2.

Post mortem. A slight skin discoloration was present near sheath. No internal lesions could be found, the viscera apparently being in normal condition.

TABLE 16*a*. Tests of physiological salt dilutions.

MATERIAL INJECTED.	Hog.	Date, 1910.	Incubation period.	Results.	Autopsy.
A. 2-hr. dilution physiological salt.	70	2 5	15 days.	Slight reaction, rec.	
B. do. do.	81	3 8	18 "	Recovered.	
B. ½-hour in physiological salt.	75	2 28	14 "	Died in 22 days..........	Slight lesions.
C. do. do.	93	3 28	14 "	" 18 "	Typical lesions.
D. do. do.	108	5 11	8 "	" 10 "	" "
E. do. do.	112	5 26	9 "	" 23 "	" "
F. do. do.	118	6 8	17 "	Mild reaction, rec.	
G. do. do.	131	6 18	18 "	Died in 23 days..........	Slight lesions.
H. do. do.	136	7 6	....	No reaction.	
I. do. do.	138	7 14	....	"	

Hog 75, a Poland China shoat, received February 28 4 cc. of a mixture of hog cholera virus and normal salt solution (1 cc. virus and 350 cc. normal salt). Fourteen days after injection symptoms of cholera were in evidence. These symptoms gradually became more pronounced, the animal dying March 22, 1910.

Post mortem. A slight skin discoloration on ventral portion of body. Spleen enlarged and pulpy. Kidneys petechiated. Liver normal. A few small ulcers at ileocæcal valve. Lungs slightly hemorrhagic.

Hog 93, Poland China, weight 55 pounds. On March 26 injected 4 cc. of mixture of virus and physiological salt solution (1 cc. virus and 240 cc. salt solution). Sickened fourteen days after injection. Symptoms those of cholera. Died April 13.

Post mortem. Lesions typical of cholera.

Hog 108, Poland China shoat, weight 100 pounds. Injected May 11 with 4 cc. dilution of virus (hog 89) in normal salt solution in proportion of 1 cc. virus to 350 cc. normal salt. Animal sickened on sixth day, refusing feed and having the general depression characteristic of cholera. Died May 21.

Post mortem. A slight discoloration of skin on ventral portion of body. Intestines inflamed throughout their entirety, and thickly studded with petechiæ. Two small undeveloped ulcers near ileocæcal valve. Spleen enlarged and hemorrhagic. Extensive extravasation of blood in kidney tissue. Liver apparently normal. Lungs thickly covered with hemorrhagic foci. Auricles hemorrhagic. Mediastinal glands enlarged and hemorrhagic.

Hog 112, Poland China shoat, weight 90 pounds, received on May 26 4 cc. of dilution of virus and normal salt solution in proportion of 1 cc. virus to 172 cc. of normal salt solution. On the ninth day feed was refused, and other signs of illness were in evidence. Had a rough, staring coat, and a general listless appearance. Would seldom leave its bed;

when it did, would walk with a tottering gait. On the eighteenth day a profuse diarrhea set in, which continued until the end. Being in a dying condition on June 18, was bled and post-mortemed.

Post mortem. Cutaneous lesions quite extensive. Blood extravasation in intestines, kidneys, lungs and heart muscle. No intestinal ulcers. This hog received approximately $\frac{1}{48}$ of a cc. of hog cholera virus.

Hog 181, Duroc-Jersey, weight 40 pounds. Injected with 4 cc. of a mixture of virus and physiological salt solution, in proportion of 1 cc. virus to 244 cc. of the salt solution. Hog was apparently normal until the eighteenth day. At this time symptoms of cholera appeared, although not as pronounced as usual. Died July 11.

Post mortem. Fair lesions.

Tables 16 and 16*a* show results obtained when susceptible hogs were injected subcutaneously, using a dosage of approximately 4 cc. per 50 lbs. weight, with dilutions of hog cholera virus in normal horse blood, *in vitro,* and in sterile physiological salt solution corresponding to those dilutions indicated in table 2*a* with horse serum virus. Attention is again called to the statement that the symbols, A, B, C, etc., in the first column of each of tables 16 and 16*a,* refer to the respective lots of the original hog cholera serum, A, B, C, etc., which were injected in the horses, as shown in table 2. Thus, in tables 16*a* and 16, hogs 75 and 79 received dilutions of the same virus in physiological salt solution, and in normal horse blood, respectively, which hogs 72 and 73, table 2*a,* received in the form of horse serum virus.

TABLE 16*b*. Summary, comparative results of dilution tests.

	Manner of dilution of virus.		
	Half-hour horse serum virus.	Corresponding dilutions in normal horse blood incubated half hour at body-temperature.	Corresponding dilutions in physiological salt solution incubated half hour at body-temperature.
Number of hogs in series	12	8	6.
Average incubation period	6.8 days	11.4 days	13.3 days.
Number of hogs recovered	1 (severe reaction)	4	1 (mild reaction).
Percentage of hogs which died,	91.6 per cent.	37.5 per cent.	83.4 per cent.
Average duration of disease	14.8 days.	18.2 days.	19.2 days.
General character of disease	Acute.	Chronic and slight.	Less acute than horse serum virus.
General character of lesions	Good	Slight, not marked.	Fair.

Table 16*b* indicates the summary of this comparative work, not including those hogs which received lots of serum represented by the symbols H and I. Reference will be made to

these below. It is necessary to state that in determining the average results in table 16*b*, relative to the virus diluted in normal horse blood, no account was taken of hog 113, which was probably naturally immune; also, in determining the per cent of normal horse blood dilution, *in vitro*, hog 80 was not considered, as death did not result from hog cholera.

It may be noted in table 2 that horse serum virus from hog cholera virus, lot F, contained an approximate dilution of 1 part of virus to 861.8 parts of diluting fluid. This dilution produced the following results (tables 2*a*, 16 and 16*a*): Horse serum virus, after six days' incubation, the death of pig 109 in nine days, with typical lesions; normal horse blood dilution, after eighteen days' incubation, the death of pig 132, with slight lesions; physiological salt solution dilution, after seventeen days' incubation, mild reaction and recovery in the case of hog 118. It was decided, therefore, to increase the dilution of hog cholera virus in the horse serum virus, in normal horse blood, *in vitro*, and in physiological salt solution, until the minimal fatal dose was reached. The purpose of this was

TABLE 16*c*. Attempted determination of minimal fatal dose of hog cholera virus, dilution physiological salt solution.

Hog No.	Date, 1910.		Virus obtained from	Dilution in physiol. Salt.	Approximate amount injected.	Incubation period.	Result.	Autopsy.
112	5	26	Hog 97	1 cc. virus, 172 cc. physiol. salt.	1/43 cc.	9 days.	Died in 23 days.	Typical lesions.
131	6	18	Hog 105	1 cc. virus, 244 cc. physiol. salt.	1/61 cc.	18 days.	Died in 23 days.	Slight lesions.
108	5	11	Hog 89	1 cc. virus. 287 cc. physiol. salt.	1/72 cc.	8 days.	Died in 10 days.	Typical lesions.
98	3	26	Hog 72	1 cc. virus, 320 cc. physiol. salt.	1/80 cc.	14 days.	Died in 18 days.	Typical lesions.
75	2	28	Hog 64	1 cc. virus, 344 cc. physiol. salt.	1/86 cc.	14 days.	Died in 22 days.	Slight lesions.
118	6	8	Hog 97	1 cc. virus, 862 cc. physiol. salt.	1/215 cc.	17 days.	Mild reaction, recovered.	
136	7	6	Hog 122	1 cc. virus, 1202 cc. physiol. salt.	1/300 cc.	No reaction.		
138	7	14	Hog 122	1 cc. virus, 1724 cc. physiol. salt.	1/432 cc.	No reaction.		

TABLE 16*d*. Comparative results of dilutions with virus, lots F, H and I.

Hog cholera serum, lot F. Dilution, 1 to 861.8; subcutaneous injection, 4 cc. per 50 lbs. weight.

MATERIAL INJECTED.	Hog.	Approximate amount injected.	Date, 1910.	Incubation periods.	Results.	Autopsy.
F. ½-hr. horse serum..	109	$\frac{1}{215.45}$ cc.	5 21	6 days.	Died in 9 days.	Typical lesions.
F. Normal horse blood dilution..........	132	$\frac{1}{215.45}$ cc.	6 23	18 "	Died in 21 days.	Slight lesions.
F. Physiol. salt dilution.............	118	$\frac{1}{215.45}$ cc.	6 8	17 "	Mild reac., rec.	

Hog cholera serum, lot H. Dilution, 1 to 1202; subcutaneous injection, 4 cc. per 50 lbs. weight.

MATERIAL INJECTED.	Hog.	Approximate amount injected.	Date, 1910.	Incubation periods.	Results.	Autopsy.
H. ½-hr. horse serum..	135	$\frac{1}{300.5}$ cc.	7 2	14 days.	Chronic case lasting 25 days. Recovered.	
H. Normal horse blood dilution..........	141	$\frac{1}{300.5}$ cc.	7 20	No reac.		
H. Physiol. salt dilution..............	136	$\frac{1}{300.5}$ cc.	7 6	" "		

Hog cholera serum, lot I. Dilution, 1 to 1724; subcutaneous injection, 4 cc. per 50 lbs. weight.

MATERIAL INJECTED.	Hog.	Approximate amount injected.	Date, 1910.	Incubation periods.	Results.	Autopsy.
I. ½-hr. horse serum..	137	$\frac{1}{431}$ cc.	7 11	No reac.		
I. Normal blood dilution..............	140	$\frac{1}{431}$ cc.	7 20	" "		
I. Physiol. salt dilution..............	138	$\frac{1}{431}$ cc.	7 14	" "		

twofold, in that the results might aid in determining whether or not horse serum virus represented mere dilution as well as indicating the minimal fatal dose of hog cholera virus. The tests with lots of serum F, H and I refer to the attempts in establishing the minimal fatal dose. Just what is the smallest amount of hog cholera virus that is capable of producing the disease is a point well worth knowing. Of course, the minimal fatal dose will vary within certain limits, depending upon the age and susceptibility of the animal and the degree of virulence of hog cholera serum. In this work the above conditions of variation have been controlled as well as possible by using 50-pound susceptible pigs from the same locality, many of which belonged to the same litters, and by making the dilutions with the same strain of serum, so activated that it produced by the subcutaneous injection of 2 cc. the death of 50-pound test pigs within fifteen days.

For the purpose of clearness, portions of tables 2, 2*a*, 16 and 16*a*, covering the tests with lots of serum F, H and I, are presented in the appended tables 16*c* and 16*d*. A study of these tables shows the approximate dilution of virulent hog cholera serum in sterile physiological salt solution which may be taken as the minimal fatal dose. Using the results obtained from test pigs 118, 136 and 138 (table 16*c*), it is suggested that perhaps the minimal fatal dose of hog cholera virus lies somewhere between 1/215 and 1/300 cc. per 50 pounds weight. It will be noticed, however, that when this dilution was used in the form of horse serum virus different results were obtained. With virus lot F, using a dilution of 1 to 861.8 parts horse blood, in the form of horse serum virus, hog 109, after an incubation period of six days, promptly died from acute hog cholera, while the corresponding normal blood dilution test pig, No. 132, after eighteen days' incubation, died in twenty-one days with slight lesions, and the corresponding physiological salt dilution test pig, No. 118, showed only a mild reaction after an incubation period of seventeen days.

The results of the test of virus lot H, in a dilution of 1 to 1202, and virus lot I, dilution 1 to 1724, conform with those obtained from the tests with virus lot F. In the case of the horse serum virus, having an estimated dilution of virus, lot H, of 1 to 1202, pig 135 became sick after fourteen days and finally recovered, after having been affected with the chronic form of cholera for a number of days. Pigs 140 and 136, injected with corresponding dilutions of virus, lot H, in normal horse blood, *in vitro,* and physiological salt solution, respectively, showed no reactions. Finally, of pigs 137, 141 and 138, each injected with 1/431 cc. of virus, lot I, in the form of horse serum virus, normal blood dilution, *in vitro,* and physiological salt solution, respectively, none showed subsequent symptoms. From these results the evidence is strong that, notwithstanding certain disadvantages in attempting to accurately estimate the dilution of any given amount of fluid placed in the blood of a living animal, the horse serum virus retains a greater degree of activity as the dilution of hog cholera virus in the blood *in vivo* becomes higher, than do the corresponding increasing dilutions in normal horse blood, *in vitro,* and in physiological salt solution.

Experimental evidence points to the fact that hog cholera virus undergoes some modification when passed through the horse. Results indicate that there is at first a process of activation of the virus, which process begins immediately after the intravenous injection of the horse, and continues for a relatively short period. Observations tend to show that at the expiration of one-half hour's residence in the blood of the horse the virus attains its highest degree of activation. It is scarcely possible, therefore, that this process of activation represents a multiplication of the theoretical invisible microorganisms. Experimental evidence also shows that, after this period of activation, a continued residence of four to twenty-four hours or longer of the virus in the horse will result in a gradual decline in virulence. This phase of the process of the modification may be due to a disintegration of the virus or an accumulation of substances deleterious to the virus. The decline in the activity of the virus would, in all probability, take place to some extent in the presence of normal horse blood outside of the living body.

The above-suggested conclusions are based upon the results of the dilution tests, supplemented by the results of the field work and previous observations. From a practical point of view, perhaps the most important results of this incomplete investigation pertain to the virulent nature of ½-hour horse serum. The positive results of the series of dilution tests are almost preponderantly in favor of the dilution in the form of horse serum virus. It was recognized at the beginning that a comparison of the dilution of the virus in normal horse blood *in vivo* with that in normal horse blood *in vitro* was perhaps of slight value. The results of various investigations in other lines of work show that in normal blood outside the body the leucocytes may immediately give off inactivating materials. Other factors in the normal horse blood *in vitro* may also exert some influence, thus impairing the direct comparison of results of normal horse blood dilutions outside the animal body with those of horse serum virus. On the other hand, the results of the series of comparative tests of the corresponding dilutions of hog cholera virus, in the form of horse serum virus and physiological salt solution, are especially valuable in showing the possible activated pathogenic properties of hog cholera virus, after a residence of one-half hour in the circulatory system of the horse. When a given amount of virus is injected intravenously into the horse and a dilution of a given ratio is estimated in the blood of the living animal, it does not appear reasonable to believe that a given portion of the blood of the horse represents a like dilution when drawn one-half hour or more after the injection of the animal. Some of the inoculated virus may be carried into other channels of the circulatory system, some may be situated in the peripheries, some may have been absorbed, and finally lytic action may have depleted the hog cholera virus, or foreign serum, by the time the virus had maintained a residence of one-half hour or longer in the living body of the animal. When a given dilution of the virus is prepared in sterile physiological salt solution, however, it is reasonable to suppose that the dilution remains the same, and that if any change might take place after an incubation at body temperature of one-half hour or longer, that change would be a multiplication of virulent properties.

It therefore seems apparent that these preliminary tests tend to show that horse serum virus represents an activated form of hog cholera virus, and not a mere dilution, because of the following reasons:

1. In a series of 12 hogs, ½-hour horse serum virus produced death in 91.6 per cent of the animals, with an average incubation period of 6.8 days and an average period of duration of the disease of 14.8 days. In comparison with the above, corresponding dilutions with the same lots of virus in normal horse blood *in vitro*, and in sterile physiological salt solution, in series of 8 and 6 hogs, respectively, produced death in 37.5 per cent and 83.4 per cent of the animals, with average incubation periods of 11.4 days and 13.3 days, and average periods of duration of disease of 18.2 days and 19.2 days, respectively.

2. The symptoms of disease and the autopsies of the hogs injected with the ½-hour horse serum virus were, as a rule, characteristic of typical acute hog cholera, while those of the corresponding dilutions in normal horse blood and physiological salt solution were more chronic and less marked in character.

3. From a limited amount of data indicated in table 16*c*, it is shown that the minimal fatal dose of virulent serum, as represented by a dilution of the virus in physiological salt solution, does not indicate the minimal fatal dose when the dilution is maintained in the form of horse serum virus.

4. During extensive field work covering the experimental vaccination of approximately 850 hogs in about eleven herds,

approximately 60 animals were infected with typical hog cholera by the subcutaneous inoculation of ½ to 5 cc. of 6-hour horse serum.

From the data which is at hand, it is suggested that the following summarized comments may be made, relative to the character of experimental horse serum, hog cholera virus, and horse serum hog cholera vaccine:

1. Horse serum virus (½-hour horse serum) does not represent a mere dilution of the given hog cholera virus.
2. A residence of hog cholera virus for a half hour in the circulatory system of the horse appears to activate the virus.
3. Half-hour horse serum virus is capable of producing typical acute hog cholera when injected subcutaneously, in relatively small doses (4 cc.), into healthy hogs.
4. The minimal fatal dose of highly virulent hog cholera serum may perhaps be found at some point between 1/215 and 1/300 cc.

Experimental Hyperimmunization with Half-hour Horse Serum Virus.

The possibility of successfully producing hyperimmune serum by substituting horse serum virus for virulent hog cholera serum in the hyperimmunizing process was suggested by some of the results obtained during the laboratory and field work in 1908.[5]

It was deemed advisable, however, to first begin the study of the experimental horse serum virus and attempt to determine whether this is composed of mere diluted hog cholera serum or really activated virus. After it was found that the ½-hour horse serum produced quite constant results when injected into susceptible pigs, and that these results were more uniform than those from corresponding dilutions in normal horse blood *in vitro* and in physiological salt solution, certain preliminary tests were planned for the purpose of determining whether protective hyperimmune serum could be prepared from the ½-hour horse serum virus.

There can be no doubt but that the successful application of horse serum virus in producing active hyperimmune serum would be of distinct practical advantage. In attempting to so modify the technique involved in the preparation of the hyperimmune serum, as at present manufactured according to the original Dorset-Niles method, the practical purpose involves the reduction of expense and inconvenience attending the method. If such a modification could be successfully made, the greatest item of expense involved in the present production of hyperimmune serum would be removed. This can readily be shown by the following conservative estimate:

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[5] Bulletin 157, Kansas State Experiment Station, "Studies on Hog Cholera and Preventive Treatment," p. 57.

1. Horse serum virus assumed as hyperimmunizing agent, based upon the use of one horse for one year:

Initial cost of horse	$100 00
Feed for one year (4 tons hay, 100 bu. grain),	75 00
Labor attending horse	50 00
Total	$225 00

Virus for injecting horse furnished by test pigs. Amount of serum possible to secure from one horse in one year, 50,000 cc. Number of hogs possible to hyperimmunize with this serum, 50.

2. By the present method three to five pigs are necessary in order to furnish sufficient virus to hyperimmunize one 250-pound hog.

Cost of three to five 50-pound pigs, at $4 to $8 (approximate)	$18 00
Cost of hyperimmunizing 50 hogs, at $18.	900 00
Labor and feed, exclusive of that pertaining to hyperimmune hogs	100 00
Total	$1,000 00
Cost of hyperimmunizing 50 hogs by latter method	$1,000 00
Cost of hyperimmunizing 50 hogs by former method	225 00
Difference	$775 00

Not only would this modification lessen the cost of production, but, providing the serum were potent, it would also prove to be a valuable factor in providing a sterile virus. Large quantities of blood can be aseptically drawn from the horse, defibrinated and stored in the refrigerator for a relatively long period. On the other hand, according to the present methods of securing virus from cholera-diseased pigs, the material is frequently contaminated and must be used soon after being obtained. Assuming that this suggested modified method could be successfully applied, the manufacture of hyperimmune serum would resolve itself into a comparatively simple and convenient process. All hogs utilized in the work might well serve a twofold purpose. Of the test pigs used in determining the potency of given lots of hyperimmune serum the controls could furnish the virus to be injected into the horse, while those test animals which received protection could later be used as hyperimmunes.

In the present investigation, lack of time has afforded the accumulation of only a limited amount of data relative to the possibility of successfully hyperimmunizing with ½-hour horse serum virus. The methods by which seven immune hogs were treated with ½-hour horse serum virus, with the resulting effects on the animals, are given in the appended table (table 17):

TABLE 17. **Experimental hyperimmunization with horse serum virus.**

Hog No.	Wt., lbs.	Method of hyperimmunization.	Amount injected, cc., and time intervening between injections.	Total amt. injected, cc.	Results.
70	80	Intravenous and intraperitoneal, "quick."	100 intravenous. 400 intraperitoneal.	500	Pregnant sow, aborted, and died in 30 hours.
73	100	"Quick," intraperitoneal.	1,000	1,000	Remained well.
76	80	"Slow," subcutaneous.	100—250 11 days.	350	Pregnant sow, died in 6 hours.
77	120	"Quick," intraperitoneal.	600	600	Remained well.
77	120	"Quick," intraperitoneal.	Rehyperimmunization, 350	350	Remained well.
86	130	"Slow," subcutaneous.	130—325—650 10 da. 7 da.	1,105	Remained well.
103	125	Intravenous and intraperitoneal, "quick."	300 intravenous. 200 intraperitoneal.	500	Remained well.

With the exception of hogs 70, 73 and 76, none showed any serious effects from the injection, other than a slight soreness, which passed off in a few hours. Hogs 70 and 76 were in advanced stages of pregnancy. They became violently ill after receiving the serum. Hog 76 died the same day. Hog 70 aborted the second day, dying that night. Hog 73, which received 100 cc. of the serum intraperitoneally, became sick soon after being removed from the table. The animal vomited and showed a general depression, but was apparently again normal in four hours, and remained well.

From the few results which have been obtained, it does not appear that the phenomenon of anaphylaxis seriously interferes with the successful inoculation of immune hogs with relatively large quantities of horse serum virus.

The serums from each of the experimental hyperimmune hogs indicated in table 17, with the exception of hogs 70 and 76, were tested for potency. In performing these tests the usual technique employed in securing and testing hyperimmune serum was used. Only a relatively small portion of blood (25 to 100 cc.) was drawn from each experimental hyperimmune hog.

Table 18 shows the results of the first test. This material consisted of the blood from experimental hyperimmune hog No. 77. The blood was obtained on April 13, 1910, sixteen days after the animal had received intraperitoneally 600 cc. of ½-hour horse serum.

TABLE 18. Experiment with first drawing of serum from hog 77.

Hog No.	Wt. lbs.	Material injected.	Inoculation.		Autopsy.
			Date, 1910.	Results.	
96	100	40 cc. serum. 2 cc. virus.	April 14	Remained well.	
97	140	20 cc. serum. 2 cc. virus.	April 14	Symptoms, April 23. Bled April 26.	Typical lesions.
98	100	2 cc. virus.	April 14	Symptoms, April 23. Died April 29.	Typical lesions.

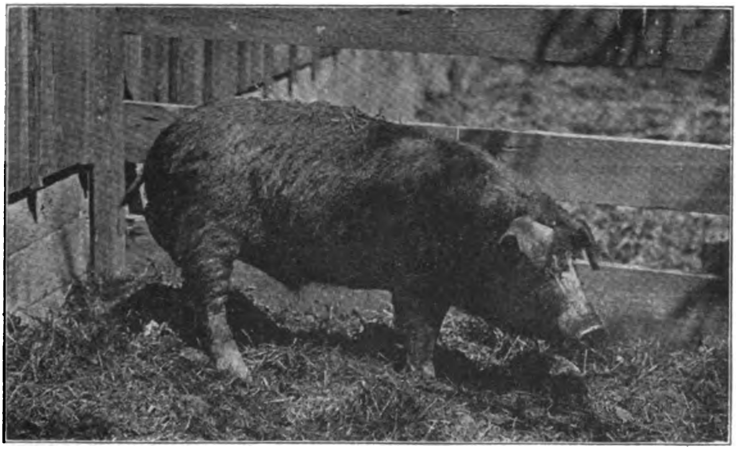


PLATE V. Experimental hyperimmune hog No. 77.

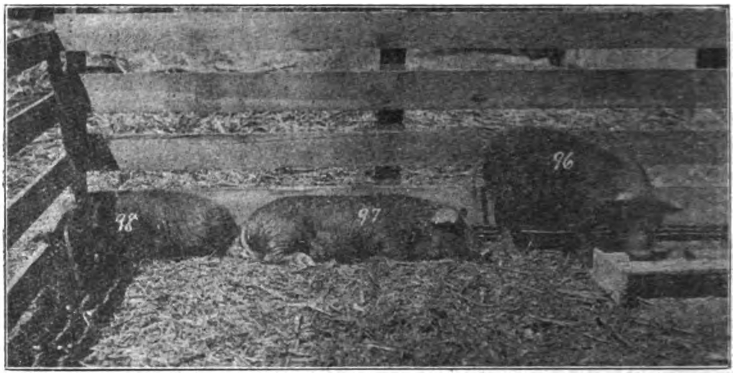
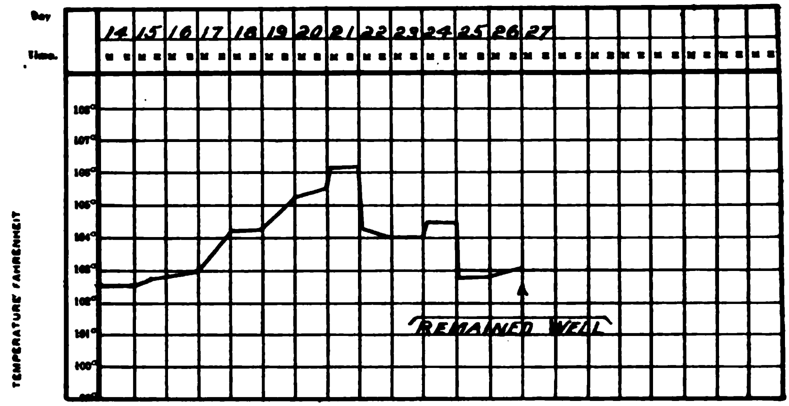
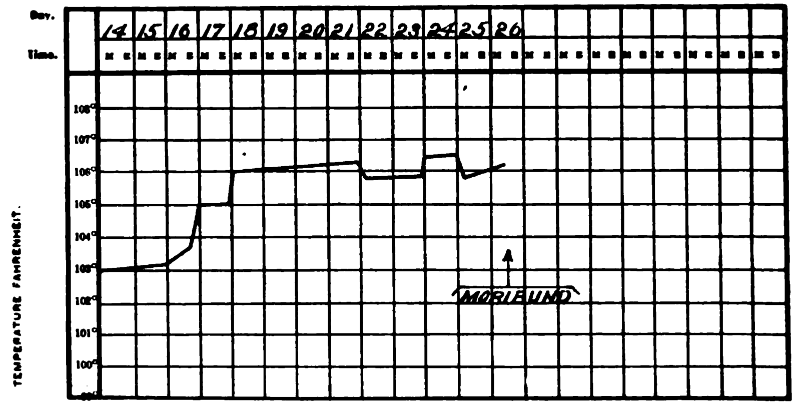


Plate VI. Test hogs 96 and 97, and control hog 98, twelve days after inoculation.

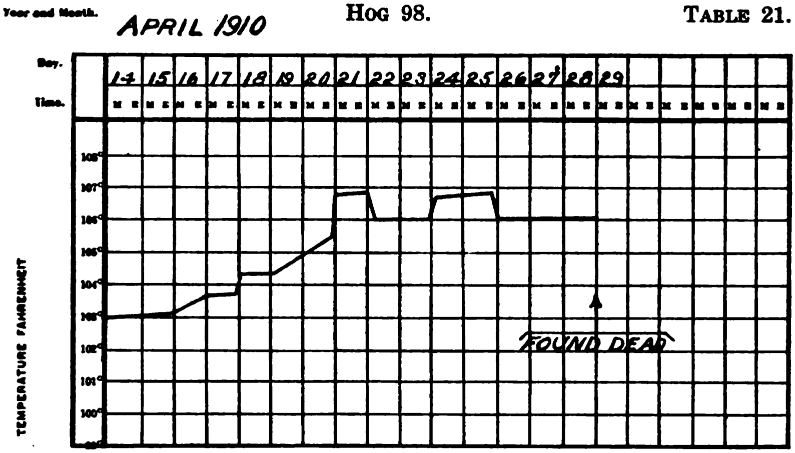
Year and Month. APRIL 1910 HOG 96. TABLE 19.



Year and Month. APRIL 1910 HOG 97. TABLE 20.



Hog 98. TABLE 21.



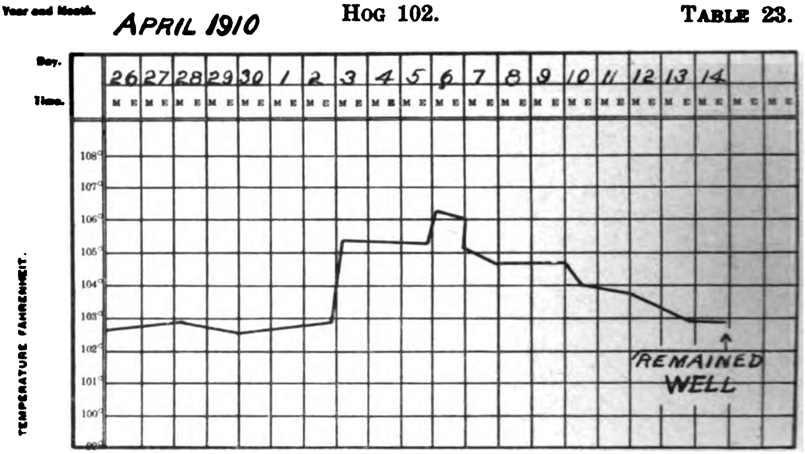
In the above test, hog 96, which received 40 cc. of the serum together with 2 cc. of virus, was fully protected by the experimental serum. Hog 97, which weighed 140 pounds and which was injected with 20 cc. of the serum simultaneously with the virus, received no protection.

Experimental hyperimmune hog 77 was bled a second time on April 20, twenty-three days after receiving the intraperitoneal injection of horse serum virus, and seven days after the first bleeding. The results of the test with this experimental hyperimmune serum are shown in table 22 and the corresponding temperature curves in tables 23, 24 and 25.

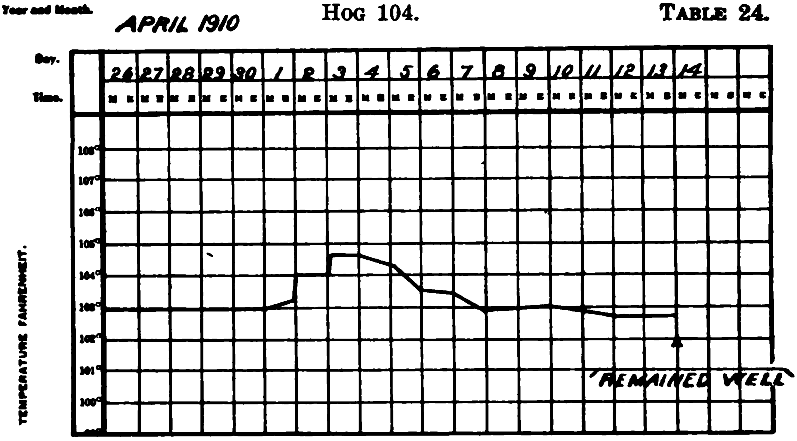
TABLE 22. Experiment with second drawing of serum from hog 77.

No. hog.	Wt., lbs.	Material injected.	Inoculation.		Autopsy.
			Date, 1910.	Results.	
102	150	40 cc. serum. 2 cc. virus.	Apr. 26	Remained well.	
104	50	20 cc. serum. 2 cc. virus.	Apr. 26	Remained well.	
105	50	2 cc. virus.	Apr. 26	Symptoms May 6. Died May 9.	Typical lesions.

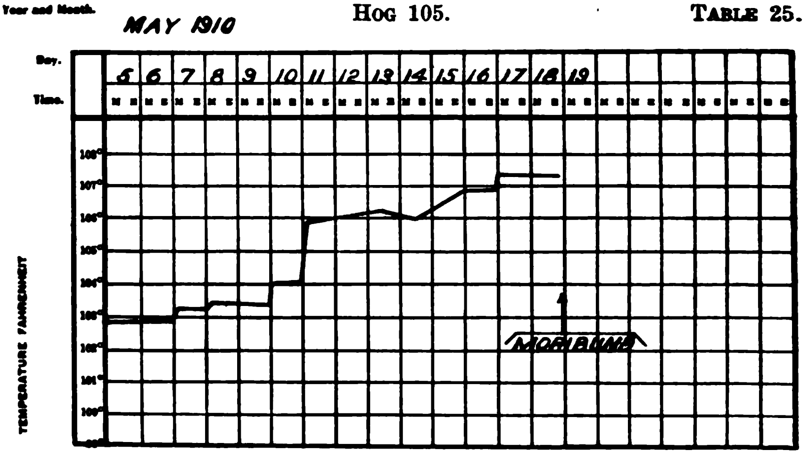
Hog 102. **Table 23.**



Hog 104. **Table 24.**



Hog 105. **Table 25.**



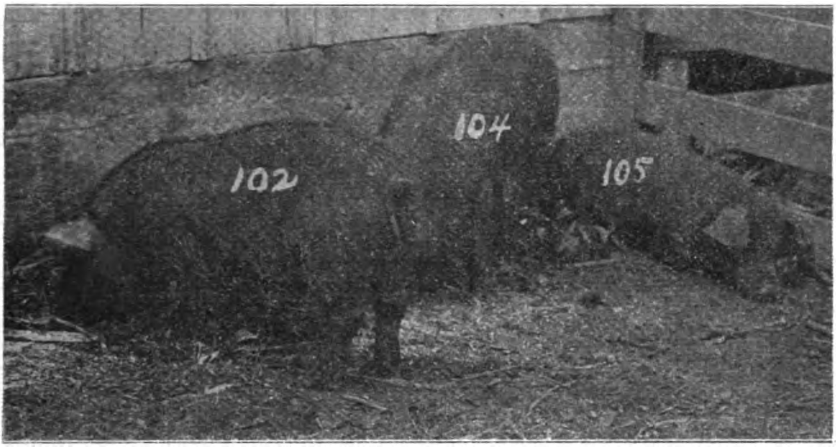


PLATE VII. Test hogs 102 and 104, and control hog 105, fourteen days after inoculation.

In the above test the control hog, No. 105, died fourteen days after inoculation, showing typical lesions of acute hog cholera. Test hogs 102 and 104, aside from thermal reactions following inoculation, remained in a normal condition.

On May 25, hog 77 was experimentally rehyperimmunized by being injected intraperitoneally with 350 cc. of ½-hour horse serum virus. A small quantity of blood was drawn from this hog on June 13, nineteen days after the injection of the virus. The test of this blood and corresponding temperature curves may be found in appended tables 26, 27, 28 and 29.

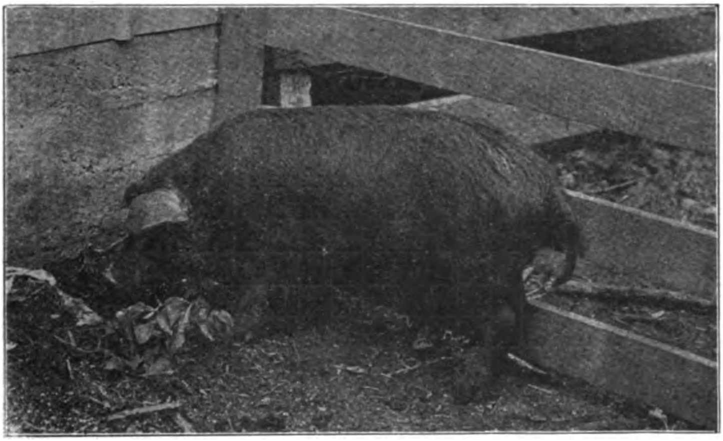


PLATE VIII. Control hog 105, fourteen days after inoculation.

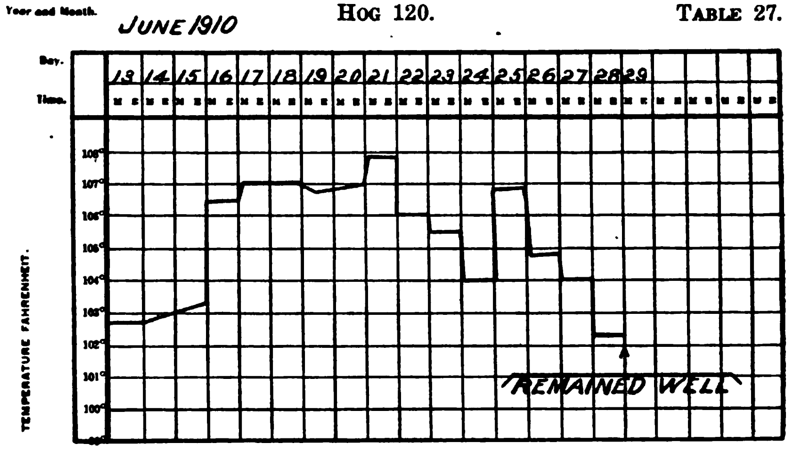
Test hog 121, which weighed 120 pounds, and which received 40 cc. of the serum with 3 cc. of virus, did not gain protection. This pig died fifteen days after inoculation, and the autopsy showed typical lesions of cholera. Test hog 120, which weighed 90 pounds and was injected with 20 cc. of the serum with 2 cc. of virus, maintained a normal condition throughout, with the exception of a marked temperature reaction.

TABLE 26. Experiment with first drawing of serum from hog 77, after experimental rehyperimmunization.

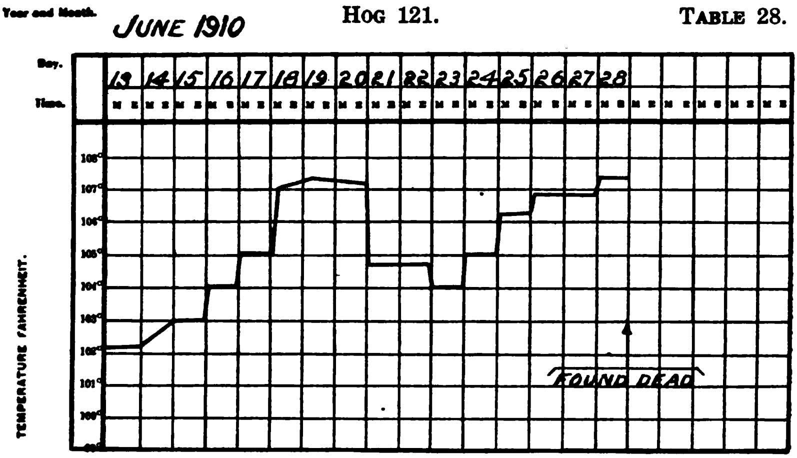
Hog No.	Wt., lbs.	Material injected.	Inoculation.		Autopsy.
			Date, 1910.	Results.	
120	90	20 cc. serum. 2 cc. virus.	June 13	Remained well.	
121	120	40 cc. serum. 3 cc. virus.	June 13	Symptoms, June 24. Died June 27.	Typical lesions.
122	110	2 cc. virus.	June 13	Symptoms, June 22. Died June 27.	Typical lesions.

Variation in susceptibility may perhaps be offered as an explanation of the result of the above test, which proved to be the only one of this experimental series which did not yield logical results. Control pig 122 showed marked symptoms of hog cholera nine days after inoculation, and died on the fourteenth day. Autopsy revealed characteristic lesions.

HOG 120. TABLE 27.



HOG 121. TABLE 28.



HOG 122. TABLE 29.

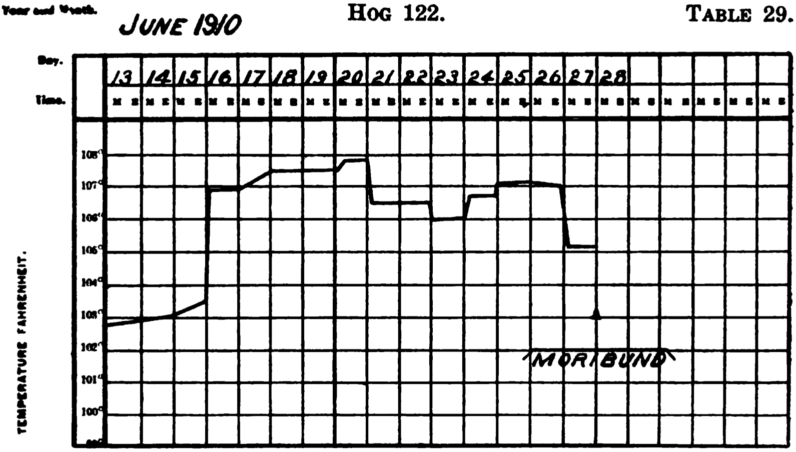


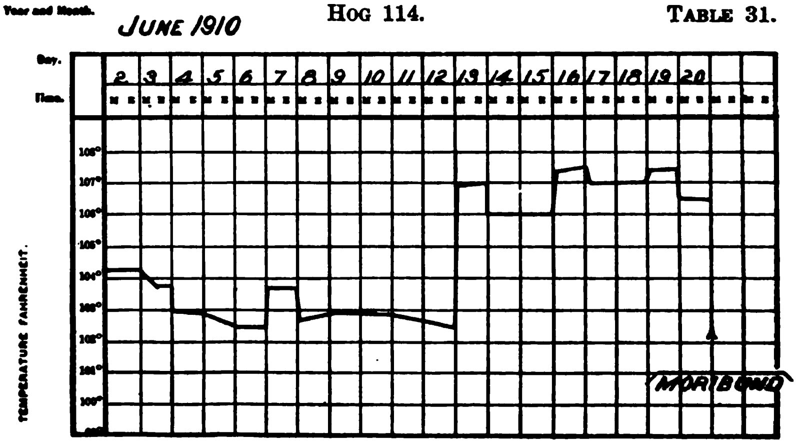
TABLE 30. Experiment with first drawing of serum from hog 73.

Hog No.	Wt., lbs.	Material injected.	Inoculation.		Autopsy.
			Date, 1910.	Results.	
114	60	25 cc. serum. 2 cc. virus.	June 2	Symptoms, June 17. Died June 21.	No marked lesions.
116	60	20 cc. serum. 2 cc. virus.	June 2	Symptoms, June 20. Died June 26.	Lesions not pronounced.
117	60	2 cc. virus.	June 2	Symptoms, June 14. Died June 19.	Typical lesions.
119	55	2 cc. virus.	June 2	Symptoms, June 9. Died June 11.	Typical lesions.

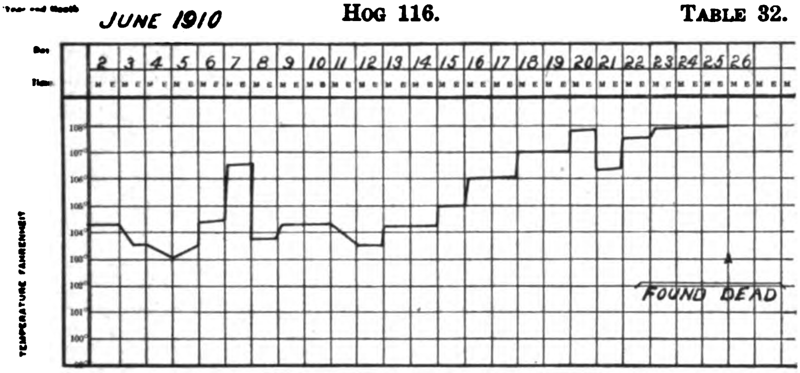
On June 1, twenty-four days after injection, experimental hyperimmune hog 73 (table 17) was relieved of 50 cc. of blood, which was tested on hogs 114 and 116. The results of this test and corresponding temperature curves are given in tables 30 to 34.

The results of the above test clearly indicate that the experimental hyperimmune serum was not sufficiently potent to furnish complete protection. At the same time, this serum evidently did possess, to some degree, protective properties. Both controls, pigs 117 and 119, manifested symptoms of the disease after twelve and seven days' incubation, died on the seventeenth and ninth days, respectively, and neither of the serum pigs, Nos. 114 and 116, showed clinical symptoms, other than a rise in temperature, which promptly subsided, until after incubation periods of fifteen and eighteen days respectively. Autopsies performed on pigs 114 and 116, which died in nineteen and twenty-four days respectively, showed no marked lesions of cholera in either case. Test pig 114, on June 2 was injected with 15 cc. of serum together with 2 cc. of virus. It was decided that this dose of 15 cc. of the serum should be increased, consequently an additional dose of 10 cc. was given the next morning, making a total dosage of 25 cc. of serum, as shown in table 30. This pig showed a shorter incubation period, and died five days earlier, than did the test pig 116, which received 20 cc. of the serum. A glance at the temperature charts of test pigs 114 and 116 shows that both animals exhibited thermal reactions after periods of time correspond-

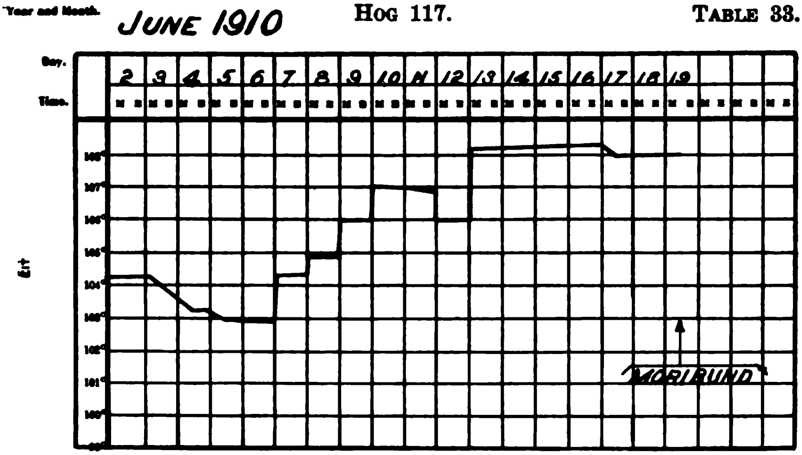
HOG 114. TABLE 31.



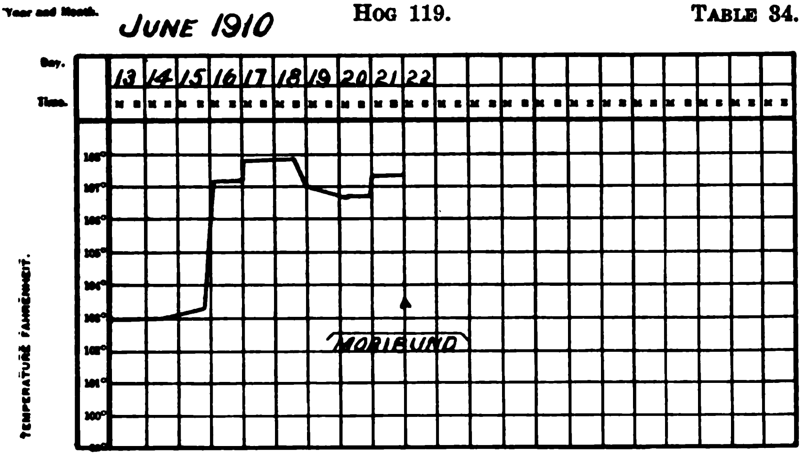
Hog 116. **Table 32.**



Hog 117. **Table 33.**



Hog 119. **Table 34.**



ing to those of control pigs 117 and 119, yet neither test pig manifested any other clinical symptoms for several days. These results, taken in connection with the fact that experimental hyperimmune hog No. 73 received a single intraperitoneal injection of 1000 cc. of horse serum virus per 100 pounds weight, possibly warrant the suggestion that while the blood contained theoretical antibodies at the time of bleeding, yet not all of the virus had been absorbed.

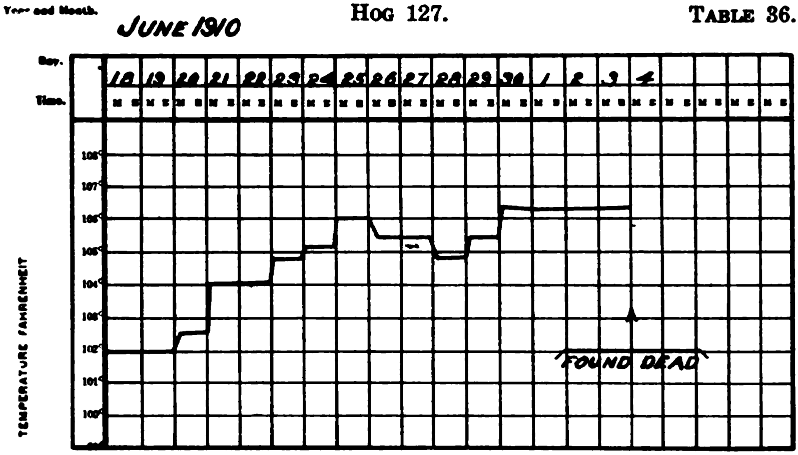
From hog 86 (table 17) 90 cc. of blood was drawn on June 10, sixteen days after the last subcutaneous injection of horse serum virus. The results from the test of this serum, which are presented in table 53, were similar to those of the preceding test. The temperature curves of the animals used on this test may be found in tables 36, 37, 38 and 39. A glance at table 17 will show that hog 86, from which this blood was taken, weighed 130 pounds and received a total of 1105 cc. of virus. It is quite possible that a portion of this virus was not absorbed when the animal was bled, sixteen days after it had received the last injection of virus. This view is supported by the fact that only in the case of two tests, those of the blood of hogs 73 and 86, which received 1000 cc. and 1105 cc. of the virus respectively, were like results obtained.

TABLE 35. Experiment with first drawing of serum from hog 86.

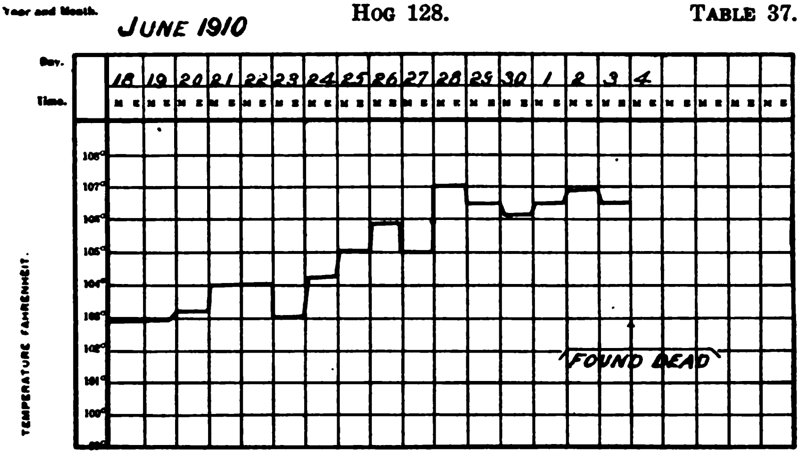
Hog No.	Wt., lbs.	Material injected.	Inoculation.		Autopsy.
			Date, 1910.	Results.	
127	60	20 cc. serum. 2 cc. virus.	June 18	Symptoms, June 30. Died July 4.	Slight lesions.
128	120	40 cc. serum. 2 cc. virus.	June 18	Symptoms, June 30. Died July 4.	Slight lesions.
129	80	2 cc. virus.	June 18	Symptoms, June 26. Died July 2.	Typical lesions.
130	85	2 cc. virus.	June 18	Symptoms, June 27. Died July 2.	Typical lesions.

Experimental hyperimmune hog No. 103 (table 17) was injected intravenously and intraperitoneally with 500 cc. of horse serum virus on May 15. On June 8, twenty-four days after the injection, 200 cc. of blood was drawn from hog 103 and submitted to test, as shown in table 40. The corresponding temperature curves are indicated in tables 41, 42 and 43.

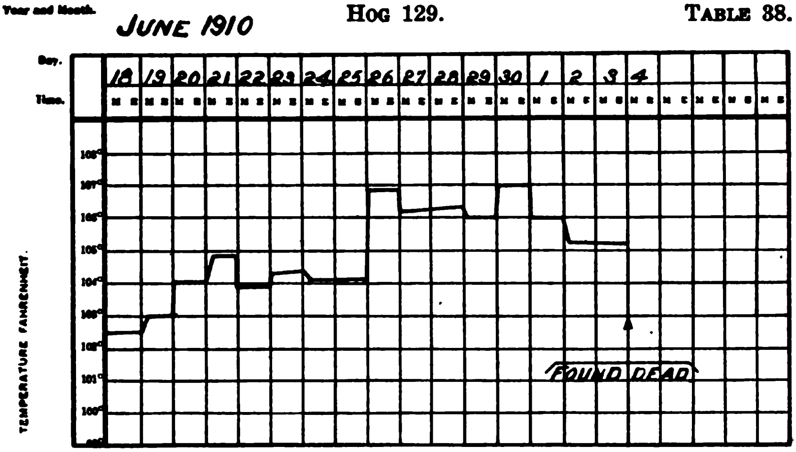
Hog 127. **Table 36.**



Hog 128. **Table 37.**



Hog 129. **Table 38.**



Year and Month. JUNE 1910 HOG 130. TABLE 39.

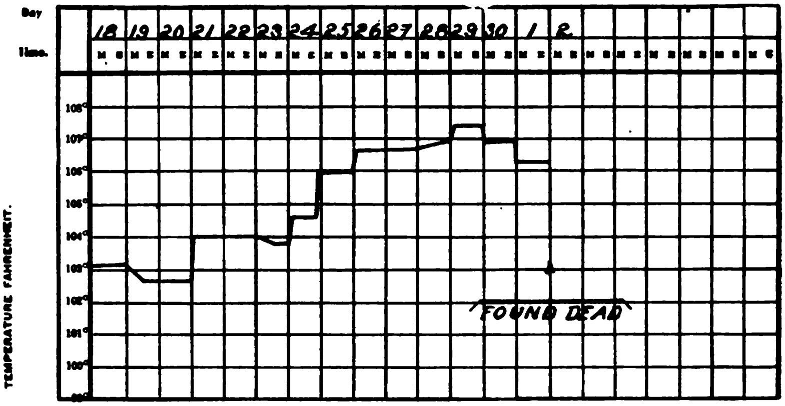
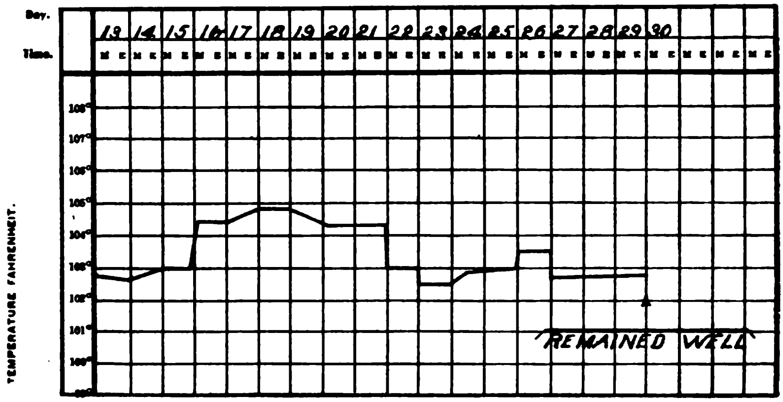


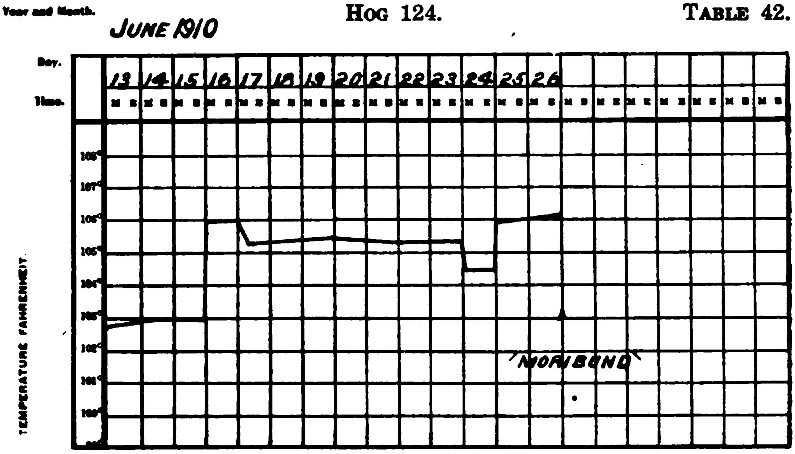
TABLE 40. Experiment with first drawing of serum from hog 103.

Hog No.	Lbs.	Material injected.	Inoculation.		Autopsy.
			Date, 1910.	Result.	
123	120	40 cc. serum. 2 cc. virus.	June 13	Remained well.	
124	100	20 cc. serum. 2 cc. virus.	June 13	Symptoms, June 22. Died June 26.	Hemorrhagic lesions.
125	100	2 cc. virus.	June 13	Symptoms, June 20. Died June 24.	Typical lesions.

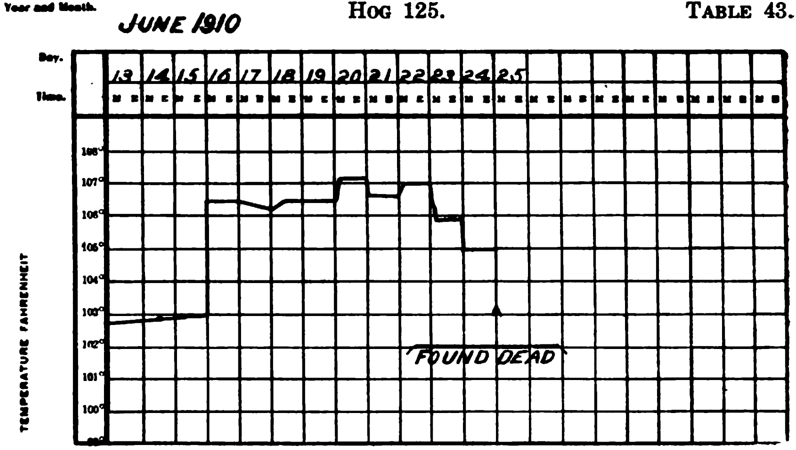
Year and Month. JUNE 1910 HOG 123. TABLE 41.



HOG 124. TABLE 42.



HOG 125. TABLE 43.



From a practical point of view the results of this test were satisfactory. Test pig 123, which weighed 120 pounds, and which received 40 cc. of the serum simultaneously with 3 cc. of virus, evidenced a marked thermal reaction a few days after treatment, thus showing absence of natural immunity. The rise in temperature subsided in five days and the animal remained normal. Test pig 124, which weighed 100 pounds, and which received 20 cc. of serum, continued on feed for a few days after the control pig, No. 125, showed severe symptoms. This pig died two days after the death of the control animal. Autopsies of the two animals showed a marked contrast, as typical lesions of cholera were present in the control pig, while test pig No. 124 showed only hemorrhagic changes, the lungs, intestines, spleen and lymphatic glands appearing normal. It should be stated that test pig 124 was not in a thrifty condition at the beginning of the experiment.

The results from the above preliminary experiments relative to the attempted hyperimmunization with horse serum virus make possible the following suggestions:

1. Horse serum and defibrinated horse blood may be injected into hogs in relatively large quantities, subcutaneously, intraperitoneally and perhaps intravenously, without danger of loss from hypersusceptibility to the foreign blood.
2. Half-hour horse serum virus, when injected into immune hogs according to the general technique employed in the original Dorset-Niles method, causes the production of protective substances in the blood of the treated animals.
3. The degree of potency of the hyperimmune serum, prepared by the experimental, modified method, may depend upon the amount of horse serum virus used and the method of application.

PART II.

HEMATOLOGICAL STUDIES.

Supplementary to the experiments outlined in part I of this bulletin, studies were made of the blood of two of the experimental horses used in the work, and of the blood of normal and diseased hogs. Inasmuch as material for hematological studies was practically always available, this phase of the work was considered of sufficient interest and importance to justify its prosecution, in the hope that the results might contribute, in some small measure, to the knowledge of hog cholera. Studies were made, therefore, (1) to observe the influence exerted by hog cholera virus, injected intravenously, upon the histological structure of horse blood, and (2) to collect additional data relative to the comparative histological structure of the blood of normal and diseased (hog cholera) swine.

Observations relative to the influence exerted by hog cholera virus, injected intravenously, upon the histological structure of normal horse blood.

In Bulletin 157 of this Experiment Station, the suggestion was made that the intravenous injection of hog cholera serum into the horse possibly caused some toxic action peculiar to the virus. As yet, no definite, positive statement can be made regarding this. It is apparent, however, that the normal horse cannot receive, intravenously, a larger dose than approximately 200 cc. of hog cholera serum without considerable danger of death. While the substitution of normal hog serum for hog cholera serum causes similar symptoms, the results afforded by limited observations show that the symptoms are much less pronounced in the case of normal hog serum. Moreover, as well as can be determined, no distinct hypersensitization follows the introduction of repeated injections of hog cholera serum into the horse. It has been observed, however, that repeated intravenous injections of hog cholera virus causes a gradually decreasing tolerance on the part of the horse toward the virus. As a possible aid in studying the nature of the action of hog cholera virus upon the horse, a number of observations were made relative to the histological structure of horse blood before and after the intravenous injection of the animal with hog cholera serum.

The usual technique was employed in this work. The red and white corpuscles were counted with the Thoma hematocytometer, Zappert ruling. For differential counts of the leucocytes, Wright's staining solution was used. The hemoglobin was estimated with Dare's hemoglobinometer. Hammerschlag's method was employed in determining the specific gravity, and Wright's method was used in estimating the time of coagulation.

TABLE 44. Treatment of experimental horses.

No.	No. of bleeding.	Wt., lbs.	Date of injection.	Amt. of virus injected.	Approximate dilution of virus.	Period of residence of virus in horse.	Lot of serum.
1	1st bleeding	1,150	12 30, 1909	100 cc.	1 to 344.7	½, 1, 2, 3½ and 9 hours,	A
1	2d "	1,150	2 12, 1910	100	1 to 344.7	½ and 9 hours	B
2	1st "	800	3 14, 1910	100	1 to 240.8	½ hour	C
1	3d "	1,150	4 4, 1910	120	1 to 287.2	½ hour	D
2	2d "	800	5 7, 1910	140	1 to 171.7	½ hour	E
1	4th "	1,150	5 20, 1910	40	1 to 861.8	½ and 1 hour	F
3	1st "	1,050	5 24, 1910	180	1 to 244.2	½ hour	G
2	3d "	800	7 2, 1910	20	1 to 1202	½ hour	H
1	5th "	1,150	7 11, 1910	20	1 to 1724	½ hour	I

Table 44, which is a duplicate of table 2, part I, shows at a glance the weight of the animals used, the amount of virus which they received and the time of bleeding. The following appended notes indicate in detail the observations relative to the treatment of the animals with hog cholera serum:

Horse No. 1, bay gelding, 15 years old, weight 1150 pounds. In good condition except lameness in fore legs, due to laminitis. Normal temperature 99.5 degrees, pulse 42, strong and regular, respiration 16.

On December 30, at 8:15 A. M., was injected intrajugularly with 100 cc. of hog cholera virus. Five minutes after receiving the virus the horse showed evidence of abnormal conditions. Pulse accelerated and respiration and temperature increased. Borborygmus pronounced. Pupils dilated and eyes had staring appearance. Animal became restless and excited. Evacuation one-half hour after injection. During the next half hour had seven evacuations, the feces being quite watery. Abdominal pains were shown, the animal striking and biting at abdomen. At the end of an hour and a half the animal was apparently normal. On February 12 horse No. 1 was injected with 100 cc. of virus. When 80 cc. had been injected the horse showed signs of uneasiness, which became more marked as he received the other 20 cc. The horse was immediately removed from the stocks. In three minutes violent symptoms appeared. The animal reeled and staggered, almost falling at times. Broke out in profuse perspiration. Pupils became dilated and conjunctiva somewhat congested. Peristalsis increased. Had passage, normal in consistency, ten minutes after injection. Numerous defecations for an hour. Epistaxis from both nostrils fifteen minutes after injection. At this time pulse 60 and respiration 30.

One-half hour after injection 1600 cc. of blood was drawn aseptically from jugular vein. The removal of this blood seemed to relieve the horse, and he immediately became more alert.

Injected again April 4 with 120 cc. virus. Twenty minutes after injection pulse and respiration accelerated. Pulse 50, respiration 21, eyes dull and staring. Had first evacuation twenty-five minutes after injection. At intervals of two minutes had six evacuations, each evacuation being more watery than the preceding one. Forty minutes after injection pulse 55, respiration 24. Perspired freely at times. One hour after injection appeared to be recovered from shock. Pulse action and respiration practically normal.

On May 20, 3 P. M., injected with 40 cc. of hog cholera serum. Ten minutes later animal neighed pitifully and seemed to be in a dazed condition. Eyes staring and expressionless. Hemorrhage from nose. Had considerable difficulty keeping on feet. Had several watery evacuations. After five minutes these symptoms gradually decreased in intensity. The 40 cc. injected this time produced a more severe reaction than the 100 cc. in former injection.

Horse No. 1 was again injected, on July 11, with 20 cc. virus. The same general symptoms appeared as in former injections, but were less violent and of shorter duration. For an hour after bleeding the horse was quite sick, refusing feed and water and frequently striking at abdomen as if intestinal pain were present. At six o'clock horse appeared to be recovered from the injection, eating and drinking well. Pulse, temperature and respiration normal at this time. The animal received a fifth injection with 20 cc. of virus on July 2. Resulting symptoms practically the same as those in the preceding injection.

Horse No. 2, gray gelding, broncho stock, weight 800 pounds; thick winded and heavey; otherwise in good condition. Normal pulse 42, rather irregular, respiration 20, temperature 99.5 degrees.

On March 14, 9 A. M., was injected intrajugularly with 100 cc. of hog cholera virus. No symptoms resulted from the injection other than that the heart action and respiratory movement were slightly quickened. Coughed and passed flatus, which was probably caused by the exercise in the lot after injection. No distinct action on intestinal tract, such as was characteristic in horse No. 1.

Horse No. 2 injected again, May 7, at 3:15 P. M., with 140 cc. of virus. No symptoms were apparent for twenty minutes. At this time breathing became difficult, and the animal was somewhat depressed. Perspired slightly, pulse quickened, irregular and weak. Had first defecation in thirty minutes, feces normal. In five minutes more another defecation, more watery than the first. One-half hour after injection 400 cc. of blood was drawn from the jugular vein. One-half hour later 330 cc. more was drawn.

TABLE 45. Horse 1, first injection, December 30, 1909.

	Erythrocytes.	Leucocytes.	Lymphs.	Large mono.	Polys.	Eosino.	Transit.	Mast C.	Hemoglobin.	Sp. gravity.	Time of coagulation.
Before injection	7,900,000	13,300	50	1.8	42	5	1.2	....	82	1.060	1 min., 15 sec.
After injection: One-half hour	5,800,000	16,700	41.9	....	50.6	6.9	....	0.4	80	1.070	3 min., 10 sec.
40 minutes	....	....	....	1	48.4	5.1	....	.2	....	....	....
2 hours	....	....	19	....	69.4	11.4	....	....	....	....	....

TABLE 46. Horse 1, second injection, February 12, 1910.

	Erythrocytes.	Leucocytes.	Lymphs.	Large mono.	Polys.	Eosino.	Transit.	Mast C.	Hemoglobin.	Sp. gravity.	Time of coagulation.
Before injection	7,600,000	11,300	49.2	0.8	40.4	9.2	....	0.3	90	1.060	5 min.
After injection: 45 minutes	6,812,000	19,250	48	.3	44.4	6.1	....	.2	85	1.050	3 min.
1 hour, 15 minutes	....	....	66.6	2.2	22.2	5.5	2.2	1.1	....	....	....
2 hours	....	....	57.3	.6	33.3	6.3	....	2.5	....	....	....
5 hours	9,200,000	10,900	21.9	.2	73.3	4	....	....	....	....	....
9 hours	....	....	33.6	1.8	53.7	10	1.1	1	....	....	....

TABLE 47. Horse 1, third injection, April 14, 1910.

	Erythrocytes.	Leucocytes.	Lymphs.	Large mono.	Polys.	Eosino.	Transit.	Mast C.	Hemoglobin.	Sp. gravity.	Time of coagulation.
Before injection: One-half hour	7,300,000	11,000	36.3	3.4	51.5	8.5	....	0.3	93	1.060	5 min., 20 sec.
After injection	6,000,000	12,500	57.7	2.5	37.6	2.2	....	....	87	1.056	3 min., 20 sec.

TABLE 48. Horse 2, first injection, March 14, 1910.

	Erythrocytes.	Leucocytes.	Lymphs.	Large mono.	Polys.	Eosino.	Transit.	Mast C.	Hemoglobin.	Sp. gravity.	Time of coagulation.
Before injection	8,600,000	12,000	50.5	1	44.5	3.3	0.7	....	....	....	....
After injection: One-half hour	6,500,000	17,600	45.2	1.4	46	5.8	.8	0.8	89	1.056	3 min., 20 sec.
1 hour, 15 minutes	7,800,000	8,400	33.3	3.5	57.1	4.7	....	1.4	....	....	....
3 hours	....	....	18.1	.4	78	1.7	.4	1.2	....	....	....
5 hours	....	....	22.5	.7	75.8	.9	....	.1	....	....	....
9 hours	....	....	19.7	.8	78.3	.8	....	.9	....	....	....

TABLE 49. Horse 2, second injection, May 7, 1910.

	Erythrocytes.	Leucocytes.	Lymphs.	Large mono.	Polys.	Eosino.	Transit.	Mast C.	Hemoglobin.	Sp. gravity.	Time of coagulation.
Before injection	8,800,000	10,800	64	0.9	30.8	2.6	0.4	1.1	95	1.060	3 min., 40 sec.
After injection: One-half hour	7,000,000	13,000	32	2.5	60	.5	....	.5	90	1.058	4 min.

TABLE 50. Horse 1, normal blood.

DATE.	Horse.	Erythrocytes per cmm.	Leucocytes per cmm.	Lymphs.	Large mono.	Polys.	Eosino.	Transit.	Mast C.	Hemoglobin.	Sp. gravity.	Time of coagulation.
Dec. 27,	1st bleeding	5,800,000	9,700	30	1	58	10	1.5	....	80	1.060	4 min.
Dec. 28,	1st bleeding	7,900,000	13,300	50	1.8	42.	5	1.2	....	82	1.060	1 min., 5 sec.
Feb. 10,	2d bleeding	8,200,000	10,900	40	1.8	48.9	8	.4	....	90	1.060	2 min., 8 sec.
Feb. 11,	3d bleeding	7,600,000	11,300	49.8	3	40.4	9.2	....	.3	90	1.060	5 min.
Apr. 2,	4th bleeding	7,800,000	11,000	36.3	3.4	57.3	8.5	....	.3	93	1.060	5 min., 20 sec.
	Average	7,460,000	11,440	41.2	2.5	49.3	8.1	.65	.12	87	1.060	3 min., 10 sec.

TABLE 51. Horse 2, normal blood.

DATE.	Horse.	Erythrocytes per cmm.	Leucocytes per cmm.	Lymphs.	Large mono.	Polys.	Eosino.	Transit.	Mast C.	Hemoglobin.	Sp. gravity.	Time of coagulation.
March 9,	1st bleeding	9,600,000	11,300	47.8	0.9	47.8	2.7	0.6	....	95	1.060	3 min., 10 sec.
March 10,	1st bleeding	8,800,000	10,200	45	6	49	5	0.4	....	95	1.060	3 min., 15 sec.
March 12,	1st bleeding	7,600,000	12,000	50.5	1	44.5	3.3	0.7	....	95	1.060	3 min., 20 sec.
May 6.	2d bleeding	8,860,000	10,800	64	0.9	30.3	2.6	0.4	1.1	95	1.060	3 min., 40 sec.
	Average	8,450,000	11,075	51.8	2.2	42.9	3.4	0.5	0.27	95	1.060	3 min., 28 sec.

Tables 45, 46, 47, 48 and 49 indicate the results obtained from the study of the blood of the horse before and after the injection with hog cholera virus. In tables 50 to 53 below are placed the averages of those results which showed evident changes in the histological structure of the blood following the injection of the virus.

TABLE 52. Comparative average results from study of the blood, horse 1, before and after three intravenous injections with virus.

	Before injection.	One-half hour after injection.
No. erythrocytes	7,460,000	6,204,000
No. leucocytes	11,440	16,150
Per cent lymphocytes	41.2	49.2
" large mononuclears	2.5	.9
" polynuclears	49.3	44.2
" eosinophiles	8.1	5
" transitional forms	.65	
" mast cells	.12	.2
" hemoglobin	87	84
Specific gravity	1,060	1,056
Time of coagulation	3 min., 10 sec.	3 min., 8 sec.

TABLE 53. Comparative average results from study of the blood, horse 2, before and after two intravenous injections with virus.

	Before injection.	One-half hour after injection.
No. erythrocytes	8,450,000	6,750,000
No. leucocytes	11,075	15,300
Per cent lymphocytes	51.8	38.6
" large mononuclears	2.2	1.9
" polynuclears	42.9	53
" eosinophiles	3.4	5.4
" transitional forms	.5	.4
" mast cells	.27	.6
" hemoglobin	95	89
Specific gravity	1,060	1,057
Time of coagulation	3 min., 23 sec.	3 min., 10 sec.

According to the results shown in tables 52 and 53, a period of residence of one-half hour of hog cholera serum in the circulatory system of the horse causes the following changes in the blood of the horse:

1. A decrease of approximately one and one-half million erythrocytes.
2. Marked leucocytosis, there being an increase of over 4000 leucocytes.
3. A loss of approximately 4 per cent of the hemoglobin.
4. A decrease in the specific gravity and slight decrease in the time of coagulation.

TABLE 54. Study of the blood of the normal hog.

Date.	Hog No. and sex.	Erythrocytes.	Leucocytes.	Lymphs.	Large mono.	Polys.	Eosino.	Transit.	Mast C.	Hemoglobin.	Sp. gravity.	Time of coagulation.
1909—Aug. 5	1 F.	4,850,000	10,070	73	1	19	5	2	....	87.5	1.058	1 min., 55 sec.
" 5	2 M.	4,600,000	10,500	70	2	16	9	3	....	90	....	2 min.
" 5	3 F.	5,800,000	10,300	70	2	23	2	3	....	90	1.055	2 min., 10 sec.
" 9	4 F.	5,900,000	19,600	64	1	28	5	2	....	83	1.058	1 min., 30 sec.
" 11	5 F.	6,100,000	11,200	62	....	35	2	1	....	79	1.060	1 min., 40 sec.
" 14	6 F.	6,400,000	12,000	58	3	34	3	2	....	78	1.060	1 min., 50 sec.
" 18	7 M.	5,850,000	14,000	55	4	30	9	.4	2	....	....	....
Sep. 30	53 M.	....	....	64.9	2.6	29	2.5	....	.6	....	....	....
" 30	54 F.	....	....	78	1.4	16	4.6	2.6	.4	....	....	....
" 30	55 F.	....	....	54	3	34	6	4	.1	....	....	....
Dec. 2	56 F.	5,960,000	19,500	69.9	1.5	25.9	.7	1.5	1.6	80	1.059	....
" 3	57 F.	7;320,000	14,500	68	3	23	2	....	2.5	78	1.060	....
" 9	58 M.	5,800,000	16,200	60.3	.5	36.6	2.2	....	.2	82	1.061	....
1910—Jan. 6	59 M.	7,600,000	18,700	38.9	....	61	.1	....	....	80	1 060	2 min., 8 sec.
" 7	60 M.	6,400,000	12,600	68.2	.4	29.6	.9	.9	....	82	1.060	3 min.
" 8	61 M.	6,000,000	17,500	59	1.9	72.2	10.6	.1	1.2	78	1.058	3 min., 3 sec.
" 8	63 M.	6,600,000	15,400	52.4	....	42.7	3.9	....	1	82	1.060	4 min.
" 13	64 M.	5,900,000	12,000	52	.5	45	2	....	.5	80	1.060	3 min.
" 24	65 M.	9,600,000	15,900	46.8	4.9	44.5	1.9	.6	.9	90	1.058	2 min., 6 sec.
" 22	57 M.	6,800,000	13,500	58	3	48	5	....	....	90	1.060	2 min.
Feb. 9	71 M.	7,800,000	26,700	55.2	3.8	33	7.7	....	.1	92	1.058	2 min.
" 29	113 M.	8,000,000	27,600	39.1	2.3	56	1.7	....	.5	94	1.060	3 min.
Jun. 6	113 M.	8,600,000	25,600	27.1	3.3	68	5.4	....	1.2	94	1.060	2 min., 5 sec.
1906—Oct. 18	178 M.	5,360,000	20,400	48	11.7	33.8	4.9	....	1.9	90	....	....
" 19	179 F.	8,616,000	10,400	41.1	10	45.7	2.2	....	.8	95	....	....
" 20	180 F.	7,120,000	28,600	56.7	10	24.4	7.6	....	1	85	....	....
" 20	181 M.	8,800,000	34,000	77.9	3.6	13.7	4.5	....	....	90	....	....
" 23	182 M.	6,728,000	19,500	53.1	18	26.8	2.8	....	.8	100	....	....
" 24	183	4,520,000	16,800	41.9	12.2	45.6	.8	....	....	90	....	....
" 24	162	5,190,000	23,600	59.8	8.4	18.7	12.4	....	.5	80	....	....
" 25	154	8,280,000	23,400	52.2	9.2	32.9	3.6	....	1.5	80	....	....
" 26	155	6,240,000	22,600	55	9.2	24.1	9.9	....	1.7	70	....	....
" 6	46	4,640,000	28,200	57.6	7.7	25.7	6.9	....	1.8	90	....	....
" 27	169	4,800,000	22,400	45.2	3.5	48.1	2.3	....	.6	90	....	....
Nov. 1	177	5,120,000	23,400	47.7	8.6	39.8	3.3	....	.6	65	....	....
" 2	122	5,600,000	24,500	38.1	7	49	5.1	....	.8	85	....	....
" 3	111	7,400,000	20,600	41.3	5.5	39.7	12	....	1.5	90	....	....
" 6	149	6,160,000	27,800	61.2	9.7	24.7	3.6	....	.8	90	....	....
" 27	184	4,000,000	12,700	44.4	11.1	38.9	4.8	....	.8	90	....	....
Dec. 11	186	8,400,000	20,000	50.3	6.7	36.3	5.8	....	.9	90	....	....
" 20	187	9,360,000	24,300	43.9	11.5	38.5	4.8	....	.1	85	....	....
" 25	188	6,450,000	39,296	41.8	15.8	38.1	2.7	....	.9	90	....	....
" 26	189	6,170,000	29,450	27.8	22.1	45.6	2.8	....	.6	85	....	....
Average		6,458,500	19,982	54.2	3.7	35.8	4.5	.4	.7	88.06	1.059	2 min., 23 sec.

TABLE 55. Study of the blood of diseased (hog cholera) hogs.

Date.	Hog.	Erythrocytes.	Leucocytes.	Lymphs.	Large mono.	Polys.	Eosino.	Transit.	Mast C.	Hemoglobin.	Sp. gravity.	Time of coagulation.
1909—Aug. 1	1 F.	......	......	48.5	2.8	88.5	0.2	8.5	8	......	......	......
" 26	2 F.	......	......	82.5	3	56	2	1	......	......	......	......
Dec. 10	56 M.	5,000,000	22,800	70.3	1.8	10	6.6	1.8	9.5	82	1.060	3 min.
" 12	56 M.	5,200,000	14,300	50.6	.9	16.3	13.6	5	18.1	80	1.060	3 min., 10 sec.
" 15	57 F.	4,600,000	16,100	46	4	22	16	......	12	78	1.059	3 min.
" 16	57 F.	5,600,000	15,000	52	2	35	3.4	.6	6	82	1.060	4 min., 2 sec.
" 18	58 F.	6,200,000	17,000	49	3	40	5	......	6	81	1.059	3 min., 2 sec.
" 20	58 F.	5,800,000	19,000	52	2	36	3.9	.1	6	82	1.056	5 min., 2 sec.
" 21	57 F.	4,800,000	18,300	67	7	23	5	......	3.5	80	1.058	4 min., 2 sec.
1910—Jan. 10	59— 7 days.	9,000,000	18,400	74.2	9	21.7	1.9	.4	.9	75	1.059	3 min., 15 sec.
" 11	60— 7 days.	6,800,000	14,900	49.7	2.6	46.6	.2	......	.9	78	1.058	3 min., 8 sec.
" 21	64—11 days.	5,000,000	14,500	60	2	35	2.5	......	.5	76	1.059	2 min., 8 sec.
" 21	61—11 days.	5,800,000	19,000	40.8	4	53.6	.8	......	.8	79	1.060	2 min.
" 26	67— 5 days.	5,900,000	15,500	41.5	2.2	46.2	9.2	.3	.6	75	1.054	3 min., 5 sec.
Nov. 7	179.	5,840,000	9,600	58.5	29.1	12.4	......	......	......	70	......	......
" 9	183.	7,600,000	23,600	72.3	8.8	16.8	2.1	......	.5	80	......	......
" 20	112.	4,480,000	7,200	46.3	29	24.7	......	......	......	50	......	......
May 7	249.	7,240,000	8,200	16.5	13.5	70	......	......	......	60	......	......
" 7	250.	4,472,000	16,590	49.2	37.2	18.6	......	......	......	60	......	......
" 7	260.	2,800,000	18,200	......	......	......	......	......	......	50	......	......
" 10	289.	5,623,000	12,710	53	16.5	23.2	.8	......	.3	65	......	......
" 15	10— 2 days.	9,056,000	9,000	27.1	42	28.5	.7	......	.4	75	......	......
Average.		5,840,500	15,515	50.3	10.5	31.8	3.5	.8	3.5	72	1.058	3 min., 19 sec.

Comparative histological structure of the blood of normal and diseased (hog cholera) swine.

According to Burnett[6] the literature contains the following summarized data relative to the structure of the blood of normal swine:

"TABLE IX. **Summary of examination of the blood of normal swine by different investigators.**

Red corpuscles per cmm.	Leucocytes per cmm.	Hemoglobin per cent.	Specific gravity.	Size of red corpuscles, microns.	Author.
6,960,000	7,840	....	....	5.26—7.9	Bethe.
7,924,000	19,000	88	....	....	Giltner.
....	....	....	....	6	Gulliver.
5,441,000	....	....	....	....	Stoltzing.
8,045,000	....	....	....	....	Storch.
4,923,000*	11,518	....	....	....	Storch.
....	....	....	1,060	6	Sussdorf.
8,668,200	....	....	....	....	Wendelstadt und Bleibtreu.

* Pigs 6—35 days old."

Drake obtained the following percentages of the varieties of leucocytes in the blood of normal swine:

		Average.
Lymphocytes	33-77%	56.4 %
Polynuclears	18-66	38.46
Eosinophiles	1-12	5.13

Giltner gives the following percentages:

Lymphocytes	30.0-79.8%	51.6 %
Large mononuclears	0.8-10	4.6
Polymorphs	13.0-60	37.0
Eosinophiles	1.2-11	5.2
Mast cells	0.2-05.6	1.3

In view of the fact that comparatively little work has been done on the study of the blood of normal hogs, it appeared necessary that as many specimens of normal blood as possible should be studied, in order to obtain comparative results of any value. Accordingly, a careful study was made of the blood of 43 normal swine. The same technique was used as in the case of the study of the horse blood. The results of this work are shown in table 54, while the results obtained from the study of 22 animals suffering from hog cholera are shown in table 55.

A comparative study of the blood from normal and diseased (hog cholera) swine showed several interesting changes in the case of hog cholera blood. The number of erythrocytes and the hemoglobin content were decreased, the anemic condition increasing according to the progress of the disease. Frequently poikilocytosis was observed in the blood from severe cases of the disease.

---

[6] Burnett, textbook, "Clinical Pathology of the Blood of Domesticated Animals," p. 48.

Leucopenia was shown in the blood of the diseased hogs, there being an average decrease of nearly 5000 leucocytes per cmm. This depletion in leucocytes, as shown by the average differential counts, involved the decrease of 4 per cent of lymphocytes, 4 per cent of the polynuclears and 0.1 per cent of the eosinophiles. The blood from diseased hogs contained an average increase of 4.8 per cent large mononuclears, 2.8 per cent mast cells and 0.8 per cent transitional forms.

The specific gravity was slightly lowered and the time of coagulation increased one minute.

These results suggest that the changes in the structure of the blood of hogs suffering from hog cholera are analogous to those in cases of typhiod fever in man.

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Kansas State Agricultural College.

EXPERIMENT STATION.—Bulletin 172.

ED. H. WEBSTER, *Director.*

FARM BULLETIN.

Entomology and Zoology Department.

THOMAS J. HEADLEE, *Entomologist and Zoölogist in Charge.*

THE PRAIRIE POCKET GOPHER (*Geomys bursarius*).

The Pocket Gopher.

BY

THEO. H. SCHEFFER,
Assistant in Zoölogical Investigations.

MANHATTAN, KAN.
SEPTEMBER 3, 1910.
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KANSAS STATE EXPERIMENT STATION,
DEPARTMENT OF ENTOMOLOGY AND ZOÖLOGY.
MANHATTAN, KAN., October 5, 1910.

Ed. H. Webster, Director:

SIR—The supply of station bulletin No. 152, entitled "The Pocket Gopher," has now become exhausted and the demand on the part of alfalfa growers and others has not abated. The author of that bulletin has, therefore, prepared a revision of the matter contained, and I hereby recommend the publication of this revision as regular farm bulletin No. 172. Respectfully, T. J. HEADLEE.

THE POCKET GOPHER.

By Theo. H. Scheffer.

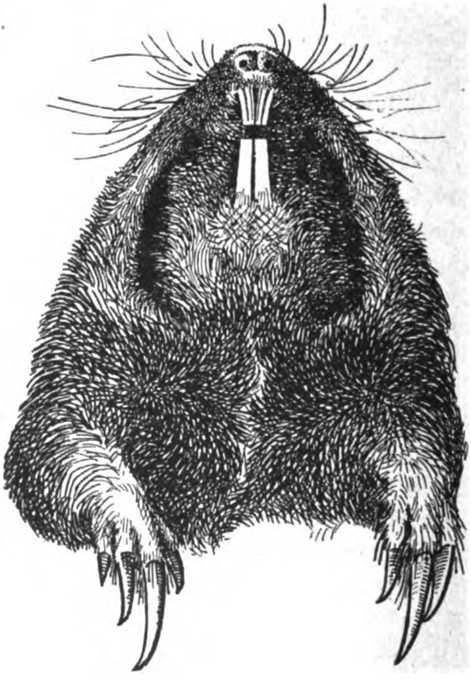
INTRODUCTORY REMARKS.

The important bearing of pocket-gopher problems on agricultural interests has become very apparent in recent years. No other species of native mammals of the state will rank with the pocket gopher in extent of injury to crops and obstruction to work in harvesting them. From an economic standpoint, therefore, the gopher is our most destructive mammal. There can be no doubt, either, that the numbers of the animal are increasing from year to year, especially in the alfalfa-growing districts of central Kansas. In many localities there are ten gophers now where there was but one a few years ago. With the steady increase in the acreage of alfalfa one may expect to see still more rapid multiplication of the species. This valuable crop (alfalfa) furnishes just the conditions necessary to make life easy for a pocket gopher. The roots of the plant are thick and succulent and extend deep enough to supply the wants of the animal in his natural range, or even when he is burrowing below the limits of frost. This food supply never fails. Then, too, the ground is not broken up by the plow for a period of years and the surface scraping given by the harrow or disk does not in the least disturb these burrowing rodents. Consequently vigilance on the part of every landowner and coöperation with his neighbor—nothing short of this—will rid a community of the pocket gopher. We cannot hope to exterminate the animal, for the conditions under which he lives are such as to render extermination practically impossible. Like mice and rats, the gopher is probably with us to stay. But the farmers of any community, as well as any individual landowner, can secure immunity from the ravages of the pest at little cost of time and labor. More than one thrifty farmer has assured me that if one keeps careful watch of his acres, the career of any invading pocket gopher can be nipped short at an expenditure of time totaling not more than a few hours a year. The history of the prairie-dog and his elimination from the agricultural problems of western Kansas well illustrates what can be done in the case of the gopher. It is no longer a matter of seeking a solution for the gopher problem. Solutions are at hand, but we are lacking in persistence and coöperation.

DESCRIPTION AND DISTRIBUTION.

The common gopher, *Geomys bursarius,* belongs to a family of rodents differing in many respects from that including the squirrels. The term "gopher" should therefore not be applied either to the little striped ground squirrel of our prairies or to the larger gray burrowing squirrel, Franklin's spermophile.

General Appearance.—Our true gopher is a short, thick-set fellow, with capacious external cheek pockets. These are wholly outside of the mouth, and are lined with soft hair of a lighter shade than that covering the body. The latter is dark brown in color, lighter beneath, and so soft and silky that it is not readily soiled by contact with damp earth. Sometimes there are white patches of various sizes about the nose



Head of prairie pocket gopher, showing entrances to cheek pockets and grooved upper incisors.

and throat. Occasionally a pure white specimen is taken. The tail is short and scantily covered with hair. The bead-like eyes are about as large as a No. 5 shot, and external ears are likewise not much in evidence. The incisor teeth are long and prominent, the upper pair being grooved longitudinally.

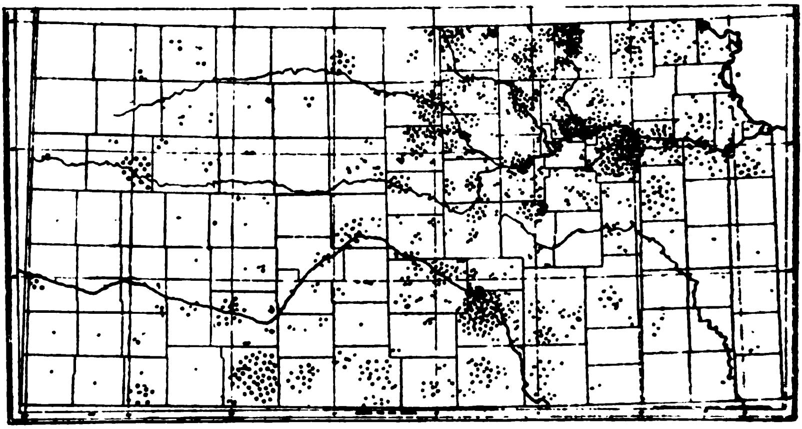
Size.—The adult animal varies somewhat in size in different parts of its range. Specimens taken about Manhattan average ten to eleven inches in length from tip of nose to tip of tail. The latter is about three and one-fourth inches long. The hind foot measures one and one-third inches. The average weight is very close to twelve ounces. The males are heavier, larger, and broader in the shoulders than the females.

Distribution.—The prairie pocket gopher, *Geomys Bursarius*, is distributed over that part of the upper Mississippi valley which includes the central and eastern parts of the Dakotas, Nebraska and Kansas, the whole of Iowa, and portions of Missouri, Illinois, Wisconsin and Minnesota. On the west—excepting in the Dakotas—its range meets and partly overlaps that of the plains pocket gopher, *G. lutescens*, and on the south that of the Louisiana gopher, *G. breviceps*. In the western part of the Dakotas *Geomys* is replaced by a distinct genus—*Thomomys*—inhabiting nearly the whole of the Rocky Mountains and Pacific regions.

Front foot of prairie pocket gopher.

Kansas Species.—In Kansas the dominant species of gopher is *G. bursarius*. It is most abundant in the central and northeastern parts of the state, and ranges at least as far west as the ninety-ninth meridian. Here it is partly, and a little farther west fully, replaced by the paler, sand-colored species, *G. lutescens*. Whether the two species intergrade on the common border of their respective ranges I have not been able to determine. At any rate, a discussion of this matter comes within the province of a technical rather than an economic bulletin. In no part of western Kansas have I found the plains pocket gopher very plentiful. It is more scattering in its distribution than *G. bursarius*, being locally abundant only in the gravel flats along the streams or among the sand-hills. The harder soil of the buffalo-grass tracts has little attraction for this burrowing animal. In the lower Arkansas valley of south-central Kansas the species becomes as abundant, however, as does *G. bursarius* in any quarter of the state.

Distribution Map.—If reports of depredations by pocket gophers and demand for measures of repression and extermination can be taken as an index to distribution, it may be seen from the accompanying map that *Geomys bursarius* is most abundant in the region drained by the Kansas river and the lower courses of its main tributaries. The area of greatest infestation is also shown to include that portion of the Arkansas valley east of Great Bend, but here the plains species is the more abundant. A personal survey of the valleys of the Kansas, the Blue, the Republican, the Solomon, the Smoky Hill and the lower Arkansas valley confirms the evidence of the map to which I have referred. Southeastern Kansas seems to be comparatively free from the pest, at least in numbers sufficient to make it troublesome. In this region and along the south-central border of the state the range of *G. bursarius* probably meets that of the Louisiana pocket gopher, *Geomys breviceps*. The evidence of this is shown by specimens from the valley of the Ninnescah—now in the zoölogical collection at Washington—having some characteristics of both species.



Distribution map. The number of dots represents the number of cans of gopher poison sent out by the Station to various points in the state up to the year 1908. The distribution of the dots will thus serve to indicate roughly the local occurrence or absence of the pest in destructive numbers.

HABITS.

The pocket gopher is an excellent illustration of an animal adapted to a particular environment. Built short and stocky, like a Hungarian miner, it is able to excavate with ease and dispatch the intricate system of long, branching, subterranean galleries in which it spends practically its entire life. Its shoulders are broad and its fore legs strong and sinewy, ending in stout claws that can rapidly rake a passage through a wall of earth. In mining operations the claws are assisted by a pair of long and sharp incisor teeth curving from the upper jaw. Its eyes are very small and their range of vision quite limited, as has been proven by experiments with animals kept in captivity. In fact, the animal can have no possible use for eyes except in the brief moments it spends at the exits of its burrow when throwing out earth. As might be expected, a study of the animal's reactions to stimuli shows that its sense of touch and of smell are exceptionally well developed. The short, stubby tail, nearly devoid of hair, is particularly sensitive to touch.

The greater number of burrowing mammals, like the prairie-dog, the spermophile and the woodchuck, spend most of the daylight hours in fine weather aboveground. The interesting little kangaroo rats and their ilk come out at night to thread their tiny pathways in the sand fields or report their errands in delicate tracery on patches of snow. The pocket gopher, on the other hand, cares neither for the enticing warmth of sunshine nor the witchery of moonlight, but sticks to the darkness of his tunnels. In watching gophers push out the earth when extending their burrows I have never seen one expose more of the body than the head, and usually one can catch a glimpse of the nose only, as with a quick upward flirt of this member the animal flings the dirt from the exit. As the earth is sometimes pushed to a considerable distance from the temporary opening, it is likely that the gopher must of necessity emerge entirely from his burrow at times. This he no doubt does under cover of darkness, for it is a matter of common observation that after a busy hour or so in the early morning very little dirt flies until near sunset, except perhaps on dark, cloudy days. No evidence of tracks or traces of foraging indicates that the animal ordinarily ventures farther than its mound of earth, however, even in the night. At certain seasons, though, particularly when many of the young generation of that year are setting up in business for themselves, the natural instinct of all animals to extend the limits of their range impels the gopher to roam about. This is evidenced by the sudden appearance in late summer and in autumn of new mounds, like pioneer shanties, in fields remote from other gopher habitations. At this season we occasionally encounter a claim seeker abroad even in the daytime. In late autumn and early winter, too, the males no doubt wander about more or less.

The Burrow.—Except where an invader has recently established himself in new territory, it is practically impossible to determine the limits of a gopher's burrow. The work of excavating is usually carried on at a depth of eight to ten inches below the surface of the ground, but the animal sometimes ranges lower in loose, sandy soil where succulent roots penetrate deeper. The average diameter of the burrow of the prairie pocket gopher is about three inches; large enough that one may usually thrust the hand and arm back into it as far as he can reach. These data are easily obtained; but when one undertakes to map out the course of the main runways, the branch tunnels, and their intersections, the pockets and the short laterals, he has before him a task that might well appall a military engineer in the wilds of a jungle. In a field that is even fairly well populated by gophers the runways of different individuals must of necessity frequently intersect each other, for it cannot be supposed that all the numerous subway crossings one exposes in digging along the tunnels are parts of one animal's private labyrinth. A prairie-dog or a spermophile digs a burrow very much like that of his neighbor; but it must be borne in mind that these animals are constructing homes, not extending passageways in search of food. The gopher follows his own sweet will in mining. Here a chance for easier digging turns him aside; there a promising lead of succulent roots entices him the other way. Heading everywhere in general and nowhere in particular, he may, in the course of a year, explore the length and breadth of a field of many acres. At irregular intervals he excavates a short lateral obliquely upward to the surface of the ground. Through these the loosened dirt is carried and thrust out in heaps. The presence of a gopher is thus easily detected by the lines of mounds, varying in size from a hatful to one or even several bushels of dirt. A study of a fresh mound reveals the plan of construction. The dirt is carried out of the opening and distributed radially, very much as miners dispose of the useless shale from a coal-pit. Usually the dump extends only part way around the opening, but sometimes the mound has the shape of a cone with a crater at the top. Where surface vegetation hinders the work, the piles of dirt are more irregular.

The Mound.—In removing the excavated earth from the burrow the gopher pushes his load before him in armfuls, so to speak. At the exit it is thrown out with a quick flip of the nose until the enlarging mound compels the animal to come out and dump the material down the slopes. After these become so steep that the material rolls back into the opening much dirt still boils up from beneath under the pressure of a powerful pair of shoulders. A wrinkled ring of earth on the completed mound usually identifies the point of the last outthrusts. After scraping away a mound from the harder surface of the ground, one may search in vain for the lateral leading to the burrow. The miner has packed it so tightly that the plug is as firm as the surrounding earth. Here and there a gopher burrow enlarges into a chamber of moderate size. Some of these are partly filled with dry grass; others are used for food storage. Not infrequently one finds a pocket extending upward, as though the animal had started to dig an exit but had abandoned the task for some reason or other.

Mole Runways.—The ridges and mounds of earth thrown up by moles are often incorrectly supposed to be the work of gophers. A little careful scrutiny will soon reveal the difference. The gopher piles up the dirt on the surface of the ground, building a mound by the addition of load after load on top of that already deposited. A mole simply heaves up the dirt from beneath, forming piles which show radiating cracks. Associated with these piles are the surface ridges made by the animal when ranging in search of food. The feeding runways of the gopher never show in surface ridges.

Breeding.—But little information along this line is obtainable in the literature accessible at this Station, and some of the statements therein made are, in the light of our own investigations, found to be more or less erroneous. The pocket gopher lives such a secluded life in its underground burrows that direct observations of its breeding habits require considerable painstaking effort. I have never been able to find a litter of the young myself, although I have explored a great many burrows in studying the animal. Occasionally, though, I have run across a nest of soft, dry grass that had probably been constructed for the purpose of rearing the young.

As might be expected of animals living in such comparative security, the pocket gopher is not a very prolific breeder. It certainly rears but one litter a year in this locality, for I have examined scores of specimens in all months of the year and have found the embryos only in late winter and early spring. The number of young in a litter varies from three to six and averages a little more than four. Very rarely only two embryos are found in the uteri.

Quite early in the spring, before the snows are fairly gone, the male gophers are said to roam about in search of mates. As I have never encountered one on such amorous errands intent I have not been able to verify the statement. It is entirely probable, however, that for reasons of personal safety such excursions are undertaken mainly after nightfall. If the statements concerning the wanderings of the male are correct, the period of gestation is short, for the young are nearly all born, in this locality, in March and April. It seems more probable, though, that mating takes place in late fall as well as in early spring; perhaps also during milder periods of the winter, as fairly well developed embryos are found in the uteri from January to May. The following table gives the results of some investigations conducted in 1907 and 1908.

It will be seen that of the ninety-five females examined some showed signs of pregnancy in the latter part of January, and all but two or three had given birth to their young before the first week in May. The record for some parts of the season is not so complete, however, as it should be. It should include data for the remainder of January and for the first half of March.

The young are described as being entirely hairless, with transparent skin of a delicate pinky-white. They are blind, their ears are sealed, and in most respects, therefore, they are perfectly helpless. In the fall one may still distinguish the younger specimens by their smaller size, but most of them seem to be fully grown by the advent of cold weather. Long before this time they have excavated burrows of their own and laid up some stores for the winter.

Number of females examined.	Date.	Number of embryos.	Stage of development of embryos, etc.
	1907.		
4	Feb. 27	0	No sign of pregnancy.
2	Mar. 15	4,5	1 lot nearly fully developed, the other a little less so.
4	Mar. 18	5,5,0,0	1 lot only slightly developed; 1 lot about an inch long, thick as one's finger; 1 female evidently pregnant, but fœti not distinguishable; 1 female no signs of pregnancy.
1	Mar. 19	0	Uteri congested, but fœti not distinguishable.
2	Mar. 25	3,4	1 lot size of thumb; 1 lot size of peanut kernel.
2	Mar. 26	1,0	1 lot size of peanut kernel; 1 female gave evidence of having been suckled.
2	Apr. 1	3,4	1 lot size of pea; 1 lot size of peanut kernel.
3	Apr. 4	4,4,5	2 lots size of end of thumb; 1 lot size of peanut kernel.
3	Apr. 5	4,4,5	2 lots size of end of one's finger; 1 lot size of peanut kernel.
1	Apr. 8	0	Evidence that young had been born.
3	Apr. 9	4,4,4	2 lots fœti in early stages of development; 1 lot size of end of thumb.
3	Apr. 15	5,5,0	2 lots fœti size of hulled peanut; no fœti distinguishable in other female.
2	Apr. 22	4,4	1 lot size of pea; 1 lot size of hulled peanut.
2	Apr. 24	4,3	1 lot in early stage of development; 1 lot size of end of little finger.
2	May 3	0,0	Young evidently born; milk in glands of females.
5	May 7	3,0,0,0,0	1 lot of fœti size of pea; 2 females showed no signs of pregnancy nor of having had young; 2 females had milk in glands.
10	May 13	2,4,0,0,0 0,0,0,0,0	7 females contained no fœti and gave no evidence of suckling young; 1 female had milk in glands; 1 lot of fœti size of pea; 1 lot size of Lima bean.
7	May 14	0,0,0,0 0,0,0	No trace of fœti or evidence of suckling young.
10	May 20.	0,0,0,0,0 0,0,0,0,0	Of the 10 females none carried fœti and only 3 gave evidence of being suckled.
	1908.		
2	Jan. 31	0,4	1 female showed no signs of pregnancy; 1 lot of fœti size of peanut kernel.
4	Feb. 5	5,0,0,0	1 lot of fœti size of pea; 1 female no traces; 2 females had congested uteri.
5	Feb. 7	5,0,0,0,0	1 lot fœti size of peanut kernel; 2 females no traces; 2 females with congested uteri.
3	Feb. 8	0,0,0	2 females no traces; 1 female with congested uteri.
9	Feb. 10	6,6,5,0,0 0,0,0,0	1 lot size of pea; 1 lot size of peanut kernel: 1 lot size of end of little finger; 2 females no traces; 4 females with congested uteri.
4	Feb 12	4,0,0,0	1 lot size of pea; 1 female no traces; 2 females with congested uteri.

NATURAL FOOD.

The natural food of the pocket gopher consists of the fleshy roots and underground stems of various plants growing wild on the prairies. To this bill of fare he adds occasionally a small quantity of succulent vegetation drawn down into his burrow from the surface at points where exits are dug for removing earth. When foraging thus above ground he loses no time in cramming supplies into his cheek pockets and hurrying below to eat the stuff at his leisure. The underground stems and roots he encounters in extending his burrows are cut into short pieces of convenient length to carry, provided he does not care to dine upon the spot. The sections thus made are commonly an inch or two in length, sometimes shorter, but I have found stores of alfalfa roots in which dozens of the pieces ranged from four to eight inches long. These, of course, the animal must carry or drag to the storeroom without the aid of his pockets. The same is necessarily true of the large cultivated tubers he often steals from the fields or bins of the unlucky farmer. Observations on the habits of a pocket gopher kept in captivity by Doctor Merriam, of Washington, D. C., seemed to indicate that the animal when thus storing his larder can travel as easily and as readily backward as forward. The writer states that the gopher moved back and forth from food supply to storeroom like a shuttle on its track, rarely turning around after securing a load. In its backward progression the sensitive tail served as an organ of touch.

The underground chambers excavated for the purpose of storing food vary in size according to the supplies in sight and the demands of the season. Sometimes one will find only a handful of roots; in other places a peck or more is packed away. Indeed, when an over-industrious gopher finds his way into a pit stored with potatoes or apples he will sometimes carry away and store several bushels of them. A mound of unusually large size is pretty good evidence of the presence of food stores near by, especially if located in the immediate vicinity of a source of plentiful supplies. In some cases a part of the dirt excavated, however, is used to pack the food supplies. I have uncovered stores in which each separate piece of root was carefully separated from the others by fine dirt, much as the farmers sometimes pack sweet potatoes in sand when storing them for winter.

The popular idea that the gopher uses his cheek pockets for carrying out the earth from his burrow is certainly erroneous. I have watched many gophers at work, and noted that the process of removing the earth is always the same: the dirt is pushed ahead of the animal in armfuls. Examination of the pockets of gophers shot in the act of removing earth, or trapped at any time, reveals no traces of contained earth. At this point it might be well to state also that no part of a gopher's runway necessarily extends down to a supply of water, as currently supposed. Like many other animals that feed upon more or less succulent vegetation, sufficient water for the tissues of the body is obtained in the food.

ACTIVE SEASON.

The pocket gopher seems to be busy at any season of the year when the ground is not frozen too hard and too deep for mining operations. Not uncommonly we see mounds of fresh earth thrown up from beneath the snows of midwinter. It is unlikely therefore that, strictly speaking, the animal ever hibernates in this part of the country. During the briefer periods of particularly inclement weather in the winter no mounds are thrown up, and if the animal burrows lower then to escape the frost, as some have observed, he must dispose of the earth in tunnels or pockets previously excavated. It is my belief, however, that the gopher spends these stormy periods near the supplies of stored food. Evidence of this habit is given by certain mounds thrown up in the spring that are made up almost wholly of crumbling pellets of excrement and fragments of nest material. October and November is a season of particular activity. Impelled by the instinct that exacts obedience without forecasting the winter, the gophers then extend their runways in all directions in search of food for their underground cellars. At this time of year the best results can usually be obtained in poisoning or trapping the animals. In the spring, again, after the frost has left the ground, this activity is renewed for a time; but when the season for breeding and rearing the young comes on, extension of the burrows receives less attention.

It has been said that the gopher is a solitary animal; that no two individuals ever occupy the same burrow except in the mating season. This statement is not in accordance with my observations, for I have on several occasions trapped a second gopher by resetting at the same opening into a burrow. This was in the early fall, too; not in the mating season.

NATURAL ENEMIES.

Since the pocket gopher so seldom shows itself outside of its subterranean galleries, it has little to fear from the natural enemies of the rodent race. It is not entirely safe from attack, however, for a few sharp-eyed and vigilant foes habitually capture numbers of gophers when they come to the mouths of their burrows to push out a load of earth. Hawks and owls take toll at these favorable moments, and many a house cat has learned the trick of capturing a meal then with little difficulty.

The gopher's habit of confining active operations in mining mainly to the hours of twilight particularly favors the owls and the cat. The Great Horned owl, the Long-eared owl, and the Barn owl, particularly the last named, render valuable service in keeping down the numbers of these destructive rodents. A single pair of owls, nesting on the farm, has been known to destroy scores of gophers in a brief season. Sometimes they live on nothing else for a time, as evidenced by the pellets of bones and fur which, like most birds of prey, they invariably disgorge after a meal.

Instances of a house cat becoming addicted to the gopher habit are not uncommon. In a number of cases that were reported directly to me, mother cats brought in several gophers a day, regularly as clockwork, to their families of kittens. In many instances of reported gopher catching, however, the informant has had in mind the little striped "gopher" or ground-squirrel.

Two enemies that, in some localities, are said to hold the pocket gopher in check more than all others are the weasel and the bull-snake. The former is too scarce in most parts of Kansas to be worth considering in this relation; but the bull-snake is common enough on farms whose owners or tenants have had the wisdom and forethought to protect the natural enemies of the destructive rodent tribe.* The snake would, of course, be able to gain entrance to the gopher's burrow only when the latter was temporarily left open; but once inside he would probably remain there for some time and make things interesting for the occupants. When one is trapping gophers he will occasionally surprise a bull-snake in the act of trying to swallow the captured animal, trap and all. I have also found this snake in the burrow of the striped spermophile, helping himself to a nestful of the young of the latter, and have seen him capture and kill the adult spermophile at the mouth of its burrow.

The little striped skunk (*Spilogale interrupta*) should not be left out of account in discussing the natural enemies of the pocket gopher. I had not supposed that these animals could make their way through the burrows of the gopher, and had laid to the charge of weasels a number of cases of killing and feeding on gophers imprisoned in steel traps. Finally I resorted to setting traps a second time in the mouths of the burrows where a gopher had been partly eaten, and in two instances succeeded in capturing a little striped skunk. There was no question in either case but that the skunk had entered the burrow at some point remote from the location of the trap, for the opening through which the trap had been introduced had been carefully covered with a board and loose earth; this covering was undisturbed. In comparing this slender little skunk's body with the diameter of many of the gopher burrows in alfalfa fields, it will be seen at once that it is not a difficult matter for the skunk to make his way through the underground passages. The additional fact that, by digging, he can enter the burrow at any point and corner the occupant in some lateral or pocket tunnel renders the little striped skunk especially valuable as a gopher catcher.

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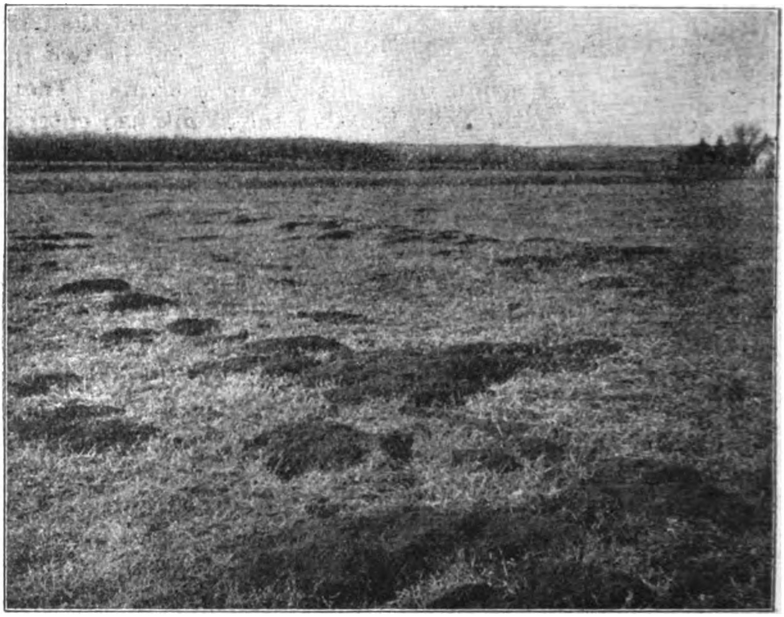
* A recent observation by Prof. J. B. Parker, of this Station, goes to show that the bull-snake sometimes worms his way by force into a gopher burrow, especially at a fresh mound.

In summary, it may be said that we cannot, except in a few favored localities, depend upon natural forces to keep in check the increase of the pocket gopher. By increasing the acreage of alfalfa we are producing the very conditions that are favorable to the most rapid multiplication of the species; and, on the other hand, by thoughtlessly or wantonly destroying harmless owls, hawks, bull-snakes, and certain mammals, we still further interfere with nature's efforts to preserve the balance of power in the animal world. The worst that can be said of the enemies of the pocket gopher is that the Great Horned owl, the weasel and the skunk sometimes destroy domestic fowls. But a little wise precaution in shutting up coops at night would prevent these inroads on the poultry industry.

CROPS DAMAGED.

The economic status of the pocket gopher has changed in the last few decades. There was a time when their work was of real benefit to the future interests of agriculture. For untold centuries they have been mixing the soil of the prairies, bringing up the subsoil to mellow, and covering up vegetation to molder and add humus to the clays and sand. But now that the virgin soil has been prepared for us we would gladly dispense with their services, for their presence is now seriously detrimental to our interests.

Alfalfa.—The damage to cultivated plants results not only from the animal's eating roots or stems, but also from its habit



View of a gopher-infested alfalfa field.

of throwing up numerous mounds of earth, which very often cover considerable areas of the growing crops and obstruct the harvesting of the remainder later. Indeed, it would scarcely be worth while, in many instances, to make such vigorous warfare on the gopher if the only issue at stake was the kind or quantity of food he pilfered. This is especially true in the case of alfalfa. No other one of the important crops of the state has suffered as much from the ravages of the pocket gopher as this valuable plant. From a gopher's standpoint, conditions of life are easy in a field of alfalfa. The ground is not worked for years at a time, at least not deep enough to interfere with the underground runways. Again, the roots of the plant are fleshy and toothsome and penetrate deep into the soil, where they may be encountered in abundance at the usual depth at which the animal ranges. They are there, too, at any time of the year to satisfy the appetite of the hungry rodent. As a result of these favorable conditions gophers have multiplied at an alarming rate in recent years wherever alfalfa is extensively grown. In the river valleys of central Kansas particularly, I have seen fields of thirty or forty acres in which one might walk over the entire tract by stepping from one gopher mound to another. It is safe to say that in these cases not less than one-fourth to one-third of the actual acreage of the field was covered, and therefore a total loss. Much of that which remained is necessarily weakened by the loss of portions of the root system.

Even a few gophers in an alfalfa field become an intolerable nuisance by obstructing the work of mowing the crop. The man who is running the machine must be constantly on the lookout for the mounds, so that he may raise the sickle-bar until the obstruction is passed. Thus much extra work is entailed and a portion of the crop is lost by running the sickle too high. If the operator does not see the mound in time it is very likely to clog the machine, or at least one or more sections of the sickle may be dulled or nicked by encountering gravel or pebbles. If the ground is reasonably mellow the horses drawing the mower stumble frequently, their feet breaking through into the runways of the gopher. Sometimes the holes thus formed are not filled again from below and the rains washing in enlarge the openings to a pit a foot or more in diameter.

Native Meadows.—Meadows of natural prairie-grasses are often invaded by the gopher to such an extent that they have the appearance of having been plowed up over many acres of their surface. The animals apparently find suitable food scarcer there than in the alfalfa field, and are consequently obliged to dig more extensive runways in search of the roots of the native plants. Unless such tracts of meadow can be freed from the pest and the surface subsequently leveled, they had better be used for pasture, as it is almost impossible to cut the grass for hay.

Orchards and Nurseries.—Young trees in nurseries and orchards, or in belts planted for shade, ornament and shelter, sometimes suffer seriously from attacks upon their root system. The gopher may gnaw off so many of the roots that the tree readily topples over; or at least it damages the system to the extent that the health of the tree is impaired and its growth stunted. The animal has the habit of following the young hedge or nursery row for some distance, taking every thing as it goes. It may then cross over and follow another row in the same manner. Fortunately for the interests of the nurseryman, the gopher never gets the foothold in plantations of young trees that it secures in alfalfa fields, by reason of the fact that the former are cultivated frequently and the ground plowed up every three or four years after the growing stock has been cleaned off. The following are extracts from letters received from prominent nurserymen and orchardists of the state:

"There has never been a year since we have planted apple-trees here, thirteen years ago, that we have not been troubled with gophers. They eat the roots of the large trees. Have never noticed that they went straight down the rows."—E. E. YAGGY, Hutchinson.

"Once I had a large Austrian pine (seven feet) gnawed off at the surface, and in a few hours afterwards the tree fell. I shot the gopher and planted another pine in its place."—H. F. CECIL, Topeka.

"The gophers have been a serious pest to nurseries or trees near grass or clover. They will sometimes go a long way through the trees if not checked. They eat any kind of wood, even the hard Osage hedge. I do not remember that they have ever eaten any grape-vines for me, but probably because they are not where they could get to them freely."—A. H. GRIESA, Lawrence.

"Will say, in regard to the pocket gopher, that we are not troubled as much now as we were a number of years ago. When we first commenced planting trees in this locality we had considerable loss from them. They do not seem to be particular as to the kind of tree. As we grew more apple-trees than anything else, our loss was heavy in that line. We found that the best manner of ridding ourselves of the gopher was to poison them."—J. H. SKINNER, Topeka.

"We have had considerable trouble with the pocket gopher and a great deal of loss. They seem to be worst with our young cherry. They sometimes run along the row for a few trees and then cross over into another row. They do not often kill more than from six to ten in one spot."—A. L. BROOKE, Topeka.

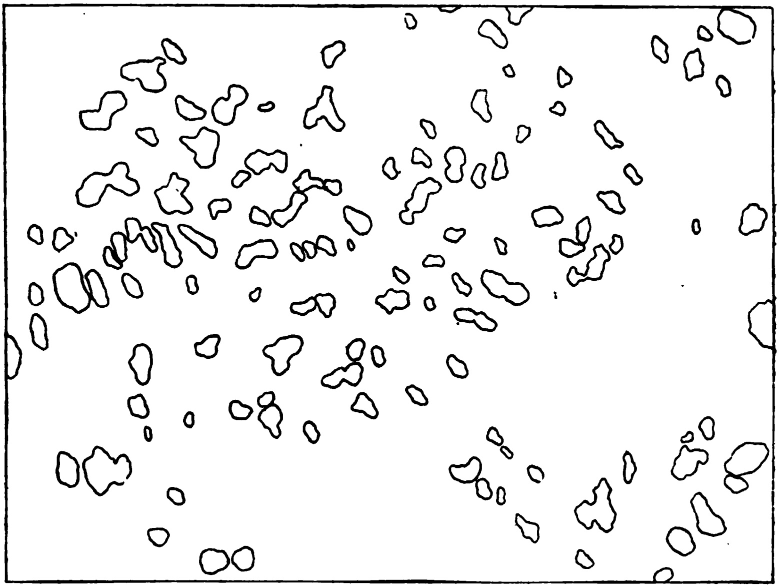
"The pocket gopher is not a great pest with us, yet does considerable damage. He does not seem to be particular as to what he destroys. The past season he has crossed a block of two-year-old cherry-trees, taking one to three trees in a row and crossing over half the block. In one place he has cut off probably fifty pear-trees (Keiffer), and in still another place a half dozen poplars, ten feet high, an inch in diameter. We like to follow with trees where alfalfa has been plowed up, but it is nearly impossible to do so on account of pocket gophers. They seem to congregate in the alfalfa, and it takes a year or two to get the land free from them."—F. W. WATSON, Topeka.

Potatoes.—Potatoes and sweet potatoes sometimes suffer seriously from the depredations of gophers, but of course the animals do not gain a permanent foothold in potato fields as they do in the tracts of ground remaining uncultivated for a period of years. They generally invade the potato ground from the surrounding fence-rows or from adjoining meadows or alfalfa fields. If no effort is made to destroy them, they will often establish themselves for a time in any part of the cultivated field. Here they eat the pieces of potato that are planted in the spring or bite off the roots of the young sweet potato plants. Later they feed upon the newly forming roots or tubers, causing the death of the plant. In the fall they proceed to harvest their share of the crop and store it in their underground root-cellars for winter use. Not content with what they may harvest on their own account, they find their way into the farmer's potato-pit and steal at their leisure. It is surprising to note the heaps of potatoes, sweet potatoes and apples sometimes carried away thus from pits and cellars and stored in chambers in the gopher's runways. In making inquiries of potato growers along the Kansas valley I have learned of several instances where the thefts amounted to five or six bushels. Prof. L. L. Dyche, writing to the Department of Agriculture, reports a case near Lawrence in which thirty-five bushels of sweet potatoes were taken from a cellar dug in rather sandy ground. To make room for their stolen treasures the rodents carry all the excavated earth into the potato cellar and pack it from time to time into the space left vacant by the removal of the tubers. The farmer, therefore, rarely learns of the loss he has sustained until he removes the contents of the cellar in the spring, when he is astonished to find, some distance below the surface, a huge pile of earth where there should be potatoes or apples. No caving in of the heap in the cellar, no piles of earth on the surface of the ground, have betrayed the gopher's work, which may have been in progress for weeks or months. By making a vigorous search the farmer sometimes recovers a part of his property, however, for the gopher's avarice has prompted him to carry away vastly more than he can possibly ever hope to eat. In the case mentioned above but two gophers could be found to answer to the charge of stealing thirty-five bushels.

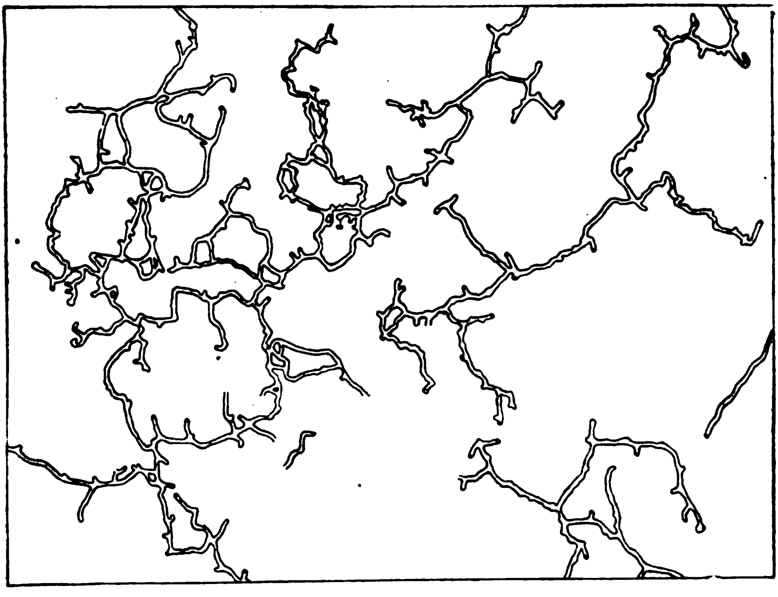
Garden Crops.—There are very few garden crops but that receive occasional attention from the pocket gopher. He does not even draw the line at the odoriferous onion, but prefers, of course, the fleshy roots, such as beet, parsnip, carrot and turnip. He is also said to have a habit of gnawing into the under side of melons and pumpkins and hollowing out the interior, sometimes filling the cavity thus formed by packing it with earth. I have not been able to verify this statement. Peanut growers suffer some loss from the depredations of pocket gophers. One correspondent, writing to the Department of Agriculture from Reeder, Kan., states that twenty-five bushels were taken from the crop grown on an acre of ground.

Small Grains.—Apparently no serious loss results from the work of pocket gophers in fields of small grain. The roots of such plants are not large enough to attract the animals. Sometimes, though, they bite off and drag stems and heads into their burrows below. When grain is in the shock, too, they often come up from beneath and carry down the heads, filling in the spaces between the sheaves with dirt. It is not fair to lay all such work to their charge, however, for they are assisted by field-mice, spermophiles and the common rat.

Irrigated Crops.—Contrary to my expectations, I did not find the gopher a serious problem in the irrigated districts of the southwestern part of the state. The prairie gopher (*Geomys bursarius*) of eastern and central Kansas is there largely replaced by the plains gopher (*Goemys lutescens*). I scarcely think the latter is as aggressive in its habits as the former; at least it has not gained much of a foothold in the extensive fields of alfalfa that have been grown in that section for years. On the other hand, this may be partly or wholly due to the flooding of the fields from the irrigating ditches several times a year. Farmers who work land under the ditch tell me that the flooding process frequently drives the gopher to the surface to escape drowning. A few such experiences probably discourage the animals so that they do not establish themselves permanently in the alfalfa and sugar-beet fields. Outside the irrigated tracts there is very little food supply except that provided by nature; hence the numbers of the species remain about the same from year to year. It is interesting to note in this connection that the western agricultural ant (*Pogonomyrmex occidentalis*) is more successful in maintaining a permanent residence on irrigated lands than the pocket gopher. The latter establishes itself permanently only on the uncultivated tracts of wild land and along fences and ditches. It prefers the loose soil of the sand-hills and gravel flats to the harder clayey soils covered by buffalo-grass.



Typical area of a badly infested alfalfa field. This tract (54 ft. x 72 ft.) was carefully mapped after first dividing it into small squares by tightly stretched lines. The small irregular patches show the shape, relative size and location of the mounds thrown up by the gophers.



Same tract as above, with all the runways carefully excavated and mapped.

Damage to Ditches.—Of course the gopher causes considerable annoyance in the irrigated districts by its excursions into the fields from its retreats along the fences and ditches. Its habit of burrowing into the banks of the ditches is most exasperating to the farmer, who, when he turns the water on, must often spend hours locating and stopping leaks. These leaks, enlarged by erosion of the water, may cause considerable loss to the farmer himself or result in damage suits from his neighbors. The water escaping in this way also softens up stretches of the public roads so as to make them impassable.

Results of Floods.—During the great flood of 1903 in the valleys of the Kansas river and its tributaries the flood-plains of many streams were inundated from bluff to bluff. At this time observers noted hundreds of pocket gophers on the higher points of land above water and along railroad embankments. An observer near Manhattan killed 180 of the animals with a club. For a year or so after the floods the lowlands were comparatively free from gophers, but they gradually reoccupied the flats and regained their original numbers.

GOPHER LEGISLATION.

The sentiment which always looks to legislative enactment for a remedy for all remediable evils has crystallized into two recent gopher laws in Kansas—the one a compulsory extermination law, the other a bounty law. The former was enacted by the session of 1905; the latter is a part of the grist from the mill of our last legislature in its regular session in 1909. There was also a bounty law passed by the special session of 1908, the provisions of which do not conflict with those of the enactment of 1909, and are therefore in force.

The compulsory extermination law—House bill No. 184, Session Laws of 1905—might be made a pretty effective weapon against the pocket gopher, but unfortunately it does not appear that township officers care to avail themselves of its provisions. From correspondence with county officers in nearly all counties of the state, I have not been able to learn of a single case wherein the law has been made operative. The law provides that, on petition of ten resident landowners of any township, the county commissioners may, at their discretion, direct the trustee of the township from which the petition came to appoint the road-overseer, or other suitable person in any road district, to see that the gophers in said district are exterminated. The person so appointed must enter the premises of every resident of his district at least three times a year on a tour of inspection. If any landowner fails to take proper measures to exterminate the gophers on his premises within five days after having been notified in writing to do so, the inspector must attend to the work of destroying the animals. The costs are then charged up in the taxes of the delinquent landowner. Other expenses incurred in the work, including a salary of two dollars per day for the inspector, are paid out of the general fund of the township. A weak point in this law is the clause which leaves it optional with the commissioners to authorize the appointment prayed for or to ignore the petition altogether. Then, too, the provisions of the law make it necessary for one neighbor to interfere in affairs that may seem to another clearly none of the former's business. He may reason that pocket gophers, because of their burrowing habits, are like weeds, practically fixtures of the soil, to be eradicated or allowed to thrive as the owner of the land pleases.

The new bounty laws *require* all counties in the state to pay a premium of five cents per head on pocket gophers or *permit* them to pay ten cents at their discretion. These laws will probably result in a considerable diminution of the pest in some localities. The bounty system in general, however, has its objectionable features, and in the particular case of the animal under discussion these features are prominent. In the first place, the gopher roams about so little above ground that each individual is practically a permanent resident of the farm on which its burrow is located. The justification for placing a price on the scalp of an animal like the coyote or puma, that may take toll from one man's flock to-day and from his neighbor's, miles away, to-morrow, is entirely wanting in the case of the pocket gopher. The principle of allowing the community at large to pay the expense of protecting the careless man's crop, while his thrifty neighbor looks after his own fields, is theoretically wrong. It imposes a double burden upon thrift.

Again, the payment of ten cents for each scalp will put a premium on trapping and tend to discourage poisoning, the more thoroughly and easily applied method of ridding a badly infested locality of these pests.

Further, the expense of maintaining a bounty system is usually out of all proportion to the benefits gained. Experience in other states, and in a few counties in this state, has demonstrated that bounties on small mammals seldom, if ever, accomplish the desired end—ridding the community of the pests. After the cream of the territory has been skimmed, so to speak, trapping becomes unprofitable and large numbers of the animals are left to again regain their ground. Long before even the skimming process is completed, however, the heavy drain on the public treasuries usually results in the repeal of the law. No state has ever been able to pay a general bounty on small mammals for any considerable length of time.

Finally, the opportunities for fraud in the matter of claiming bounties are much greater in the case of the pocket gopher than with the larger and better known mammals. The majority of county clerks to whom the scalps will be presented have perhaps never seen a pocket gopher. At least they are not trained mammalogists, and only such can, under certain circumstances, distinguish the scalp of a pocket gopher from that of some of the other small mammals. The law requires that the scalp, with the ears, be presented in evidence; but the gopher has practically no external ears. Any ingenious boy with a ticket punch can easily manufacture a half dozen legal scalps from the pelt of a single gopher. Although not specified in the law, it would be well to require the cheek-pockets to be included with the scalp. There could then be little question as to the identity of the animal.

In 1903, six years previous to the enactment of the present compulsory bounty law, an act was passed authorizing county commissioners, in their discretion, to pay a premium of five to twenty-five cents apiece for the scalps of pocket gophers and gray ground-squirrels. The scope of this law was limited, by provision, to counties east of the sixth principal meridian. Under this act eight counties have paid premiums on gopher scalps for periods ranging from three months to four years. The list of these counties follows: Atchison, Brown, Jefferson, Johnson, Leavenworth, Marshall, Morris, and Pottawatomie. Some of them report the payment of only a few dollars per year in bounties, while in other cases the amounts are considerable. Leavenworth county, for example, paid out $2480, after which the commissioners withdrew the bounty. Marshall county withdrew its bounty after paying out in the year 1907 $4200. Township trustees from all parts of the county reported at the close of the year that the numbers of pocket gophers were apparently as great in their respective townships as when they began paying bounty in the spring. Evidently the trap is slower than the gopher's rate of increase. Wholesale fraud in the matter of manufacturing several scalps from one skin was suspected in a number of cases.

If a few farmer boys in every school district in certain counties of central Kansas should become as active in the extermination of the pocket gopher as the law perhaps contemplates, those counties would soon be stamping their warrants "Not paid for lack of funds." By way of supporting this statement, let me cite two illustrations: Benton county, Iowa, paid out in three years $18,000 in bounty on gophers, at an average rate of fourteen cents per scalp. Meeker county, Minnesota, withdrew its bounty on pocket and striped gophers, or ground-squirrels, after having cashed bounty warrants to the amount of $14,056 in five months.

If the destruction of the pests is to be paid for out of the public treasury, better results can be obtained, and at a much less cost, by the plan of distributing a prepared poison free to those landowners who will agree to use it as directed. Counties that have tried this plan in other states prefer it to the bounty system. Why may we not profit also by our own experience in ridding western Kansas of the prairie-dog? Under the provisions of an act passed by the legislature of Kansas in 1903 the purchase and use of poison in all townships infested by prairie-dogs was made compulsory. All expenses were defrayed from the township treasury, the county commissioners having previously made a special levy for the purpose. The vigorous campaign that followed the enactment of this law almost wiped the prairie-dog from the face of the land. A reënactment, therefore, of the prairie-dog law of 1903, so modified as to fit the case of the pocket gopher, is, in our opinion, the wisest measure that could be adopted.

Even though we do not get a compulsory "extermination" law for the pocket gopher, the thrifty farmer would profit much by legal enactment compelling road overseers to keep down the pest on the roadsides. The same should apply also to the foremen having charge of the various sections on the railroad right of way. It is a matter of common observation that when gophers invade a clean field they usually enter from the roadsides, railroad right of way, or neglected fence row.

METHODS OF COMBATING.

Poisoning.—Gophers do not possess the shrewdness and cunning that have become instinctive in many other wild creatures because of the constant necessity imposed upon the latter of avoiding and escaping enemies. Later experience in the wiles of man has evidently taught them nothing, for they seldom reject any kind of poisoned food offered them.

As stated before, poisoning is the more thorough and easily applied method of ridding a badly infested farm of the pest. It is also the best method if the territory to be freed from gophers is of considerable extent. In either of the above cases one man can accomplish as much with poisoned bait as a half dozen could in the same time with traps. The danger of killing stock or useful birds and animals, attending the use of poison for prairie dogs, English sparrows, and the like, is entirely eliminated by the plan of introducing the bait through small openings into the gophers' burrows.

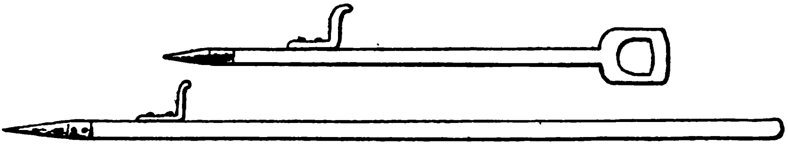
Since the pocket gopher lives naturally on the roots and tubers of native plants, or on succulent vegetation drawn down into the burrow from the surface, it follows that a close substitute for these articles will make the best bait for poisoning. Knowledge gained by personal experiments and by careful inquiry among farmers and fruit growers goes to show that pieces of potato, apple, or sweet potato, poisoned by inserting a few crystals of strychnine into slits made with the point of a knife, answer the purpose very well. Some correspondents have reported good results from soaking the baits in a solution of arsenic or strychnine. Only a mechanical mixture of the former substance can be obtained in water, however, and the presence of particles of the free poison on the surface of the bait would be more likely to cause its rejection than if they were concealed in small slits. Raisins and prunes, treated like the pieces of potato or apple, seem to be very effective baits also. Our experience with specially prepared tablets, sold under patented formulas, does not warrant us in recommending them.

There is some question as to the efficacy of any sort of scent applied to the poisoned bait. We have tried scented and unscented bait at the Station without being able to determine that one was eaten more readily than the other. All claims to superiority in certain proprietary gopher poisons, based on the use of a secret scent, may be set down as lacking the warrant of practical test. It is true that the sense of smell is probably highly developed in the pocket gopher, owing to the necessities of his underground life, but we lack evidence as to what may appeal to his tastes. Anise oil is often put on baits for various animals, but in poisoning gophers as good results are obtainable without its use.

About eight years ago the state, through a special agent, Prof. D. E. Lantz, purchased the right to manufacture and distribute within the borders of Kansas a certain proprietary poison, the active principles of which are strychnine and cyanide of potassium. This poison was intended to be used in destroying the prairie-dogs on the cattle ranges of the West, but it was found that by leaving out one ingredient—the cyanide of potassium—a very efficient poison for pocket gophers could be prepared. After the state's contract with the special agent had expired by time limit, the work of manufacturing and distributing this poison was turned over to the Department of Zoölogy and Entomology in the College. The poison is put up in the form of a syrup and sent out in quart cans to any part of the state. On each can is a printed label giving the formula used in preparing the poison and full directions for its use. The success attending the use of this syrup is evidenced by the fact that in the past six years we have sent out over 2500 cans. Experiments personally conducted on the Station grounds and elsewhere have borne out the uniformly favorable reports, from alfalfa growers, particularly, as to the merits of the poison. We therefore recommend this poisoned syrup as the best means we have discovered so far for the destruction of pocket gophers. The syrup is sold by the College at actual cost of manufacture, which at present is $1.10 per quart can.

The method of using this poison commends itself as a time saver. Pour boiling water over as much shelled corn as you will need—the quart of syrup will poison a half bushel—and let it stand several hours to swell and soften. Drain off the water and pour over the grain enough of the syrup to render it sticky when thoroughly stirred together. Sweeten the mass with a little good table syrup and add a little corn-meal to take up the excess moisture, but not enough to leave any dry meal. Cork up the syrup can tightly and place it out of reach of children and domestic animals. It will keep indefinitely and is ready for use at any time.

The soaked corn, poisoned as above, is introduced into the burrows of the gophers, a few grains at a place, by means of an old spoon. Openings into the burrows must first be made with a sharp stick—a sharpened broom handle will serve the purpose—or a spade handle shod with an iron point and having an iron foot-bar some distance from the end to aid in making the thrust. Experience will soon enable one to tell when he has struck the burrow, which can be located approximately by getting on a line between two mounds of earth. After dropping in the poisoned grain the hole may be left open, or if closed care should be taken not to allow dirt to fall in and cover up the bait. If the hole is left open the gopher is likely to be attracted by the light and find the bait the sooner.



Two forms of prod for locating runways of the pocket gopher and making openings for the introduction of poisoned bait.

The same method of introducing the poison into the burrows is employed also when raisins and prunes or pieces of apple and potato are used. The presence of freshly thrown up mounds indicates that the animal is extending his runways in that quarter, and it is best to confine one's poisoning operations to such places. If the field can be dragged over with a harrow or plank a few days after the poison has been put out, new mounds can be readily detected and fresh poison distributed. If the work was thoroughly done in the first place it usually takes but a few minutes to go over the field a second time. The few remaining gophers, if any, may become wary, and in that case they should be trapped.

A few experiments performed on a rather extensive scale seem to indicate that a more acceptable bait than soaked corn is to be found in finely chopped sweet potatoes. These potatoes are put in a box and cut up with a sharp spade until the pieces average about the size of the end of one's finger. They are then treated with poisoned syrup as in the case of the corn. This bait should be put out when freshly made, as it is likely to mold if left standing about for any considerable length of time. Potatoes, mangels and turnips were also given a trial, but they all proved to be too mushy when chopped up with the spade. The sweet potato lacks the watery qualities of these other roots and tubers and is a nearer approach to the natural food of the pocket gopher than is corn. In one field of alfalfa, consisting of about twenty acres, the sweet potato bait was used to such good effect that but a single gopher could be found throughout the rest of the season, although previous to poisoning and dragging the field it was thickly dotted with mounds. Almost equally good results were obtained at different times in two or three other and still larger fields.

The best time of the year to poison gophers is when they are most active in extending their burrows. This is usually in the late fall, for they are then laying in stores of provisions for the winter. Spring is a period of renewed activity, and poison may be successfully used at this time also. In fact, it will pay to make war on pocket gophers at any time when they are seen to be active.

Fumigation.—The use of carbon bisulphide vapor or the fumes of burning sulphur as agents for destroying the pocket gopher is not recommended by this Station. It is true that fumigation methods are occasionally followed by successful results, but under ordinary conditions the game is not worth the powder. We have other remedies for the pest that can be more easily, more effectively and more cheaply employed. An older bulletin of the United States Department of Agriculture recommends carbon bisulphide as the simplest agent for the destruction of gophers, but later advices from the same source partially discredit the former recommendations, and experiments at this Station contribute to the same result.

The ordinary method of using carbon bisulphide for destroying burrowing rodents is to pour the liquid upon a wad of cotton, corn-cob, or other porous substance, and then thrust the latter into an opening made into the burrow, closing the opening at once with earth. The bisulphide vaporizes rapidly, forming a heavy gas which is supposed to flow along the runways, smothering the occupants. This it will do in the case of animals whose burrows are short or penetrate deep into the soil. The pocket gopher, however, in his search for food ranges so near the surface of the ground that the introduced gas has plenty of opportunity to escape through the loose earth or to be absorbed. The burrows are long and intricate, branching often and in places reaching almost the actual surface, especially where the excavated earth has been thrust out or where the animal has started to dig an exit and later abandoned the work. If the ground is dry the gas is dissipated the more rapidly, so that good results might be expected only when the soil is sodden by recent rains.

With us, the plan of forcing the gas into the burrows by means of a bellows gave no better results than the methods described above. The apparatus used for forcing the gas consisted of an ordinary two-gallon kerosene can with a ten-inch hand-bellows connected by a short piece of half-inch hose to the opening at the top of the can. This end of the hose, or a tin tube attached to it, should extend nearly to the bottom of the can, so that the air from the bellows will have to bubble up through the liquid bisulphide on its way to the exit at the spout. The vapor thus formed is led into the burrow by means of another short piece of hose attached to the spout of the can. I have described the apparatus here because some who have used it in localities where there were comparatively few gophers and the burrows simple claim that they have rid their farms of the pest by this means.

In order to give the gas-pumping method a thorough test, a larger quantity of bisulphide was used in repeated experiments than has been recommended when the liquid is simply to be introduced on a wad of cotton. At each opening made into a burrow the bellows was operated four or five minutes, vaporizing from four to seven ounces of carbon bisulphide. This variation in the amount of liquid vaporized in equal periods of time was due to difference of quantity put into the can before the series of experiments was begun. The larger the quantity the more gas will be evaporated in a given period. As carbon bisulphide costs about twenty cents per pound retail, the expense of treating each burrow was therefore from five to eight cents, not counting the time of the operator. A conservative estimate will place the average cost of attempting to destroy pocket gophers by this method in the alfalfa fields and meadows of central Kansas at one dollar per acre for materials alone. Results do not justify this expense. In a series of thirty experiments personally supervised by the writer during the fall of 1906 and spring of 1907 but four were attended with successful outcome, three of these at a time when the ground was fairly well soaked by recent rains. The method of determining results in all cases was to open the burrow some hours after the introduction of the gas and then visit the spot a little later to note whether the opening had been closed. As indicated above, in twenty-six out of thirty cases it was found that fresh dirt had been pushed into the opening, showing that the occupant of the burrow was uninjured. In a series of experiments conducted at Alden, Kan., with the plains pocket gopher, ten out of twelve openings were promptly closed after the burrows had been thoroughly fumigated.

In one experiment, undertaken with particular care, a line of mounds on a gentle slope of prairie sod was selected as indicating a single, simple burrow. At a point 100 feet down the slope from the last mound in the line an opening was made into the runway and the latter sufficiently enlarged to receive a cat. In four minutes from the time the operator began pumping gas at a second opening—100 feet distant—the cat yielded its nine lives separately and individually to the cause of science. Not so the gopher, however. After pumping gas into two openings made below the point where the cat had been placed, the field was abandoned until the next day, when it was found that the gopher, or gophers, had packed some of the openings and were defiantly throwing up fresh mounds.

No experiments in forcing fumes of burning sulphur into the burrows were undertaken, but in a number of the trials mentioned above the charge of carbon bisulphide vapor was exploded by dropping a lighted match into the opening of the burrow after removing the can to a safe distance. The gas resulting from the combustion of the carbon bisulphide vapor is the same as that produced by burning sulphur—sulphur dioxide. Although no disaster to the gopher seemed to follow these explosions, the distance to which the gas had penetrated and the length and intricacies of the burrow was demonstrated by the presence of smoke or loose earth forced out at weak places.

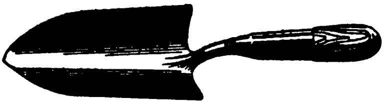
In the case of the experiment with the cat, cited above, the investigator who furnished the apparatus for the trial undertook to increase the efficiency of the gas by adding flowers of sulphur to the liquid in the can. This served only to clog the machine, however, as none of the sulphur can be dissolved in the carbon bisulphide. A certain manufacturer of a proprietary liquid for destroying pocket gophers by fumigation claims that he has added something which will increase the volume of gas arising from the bisulphide. More attention might be paid to his claim if efficiency depended upon volume alone.

Trapping.—Although somewhat slow, there is no surer method of ridding one's premises of pocket gophers than by trapping. When you have the animal fast in the jaws of a trap you are certain that his career of uselessness is over. If the gopher were as wise as a rat we would not be permitted to indulge this feeling very often, but a long series of experiments has convinced me that he will blunder into almost any sort of trap that is set for him, no matter how we set it. Long experience in the wiles of man, as a result of living in the nooks and corners of his habitations, has developed by natural selection a race of rats that is proverbial for sagacity. Such shrewdness the pocket gopher will never know, at least not until after many generations of contact with his sworn enemy, man. On the other hand, it is true that a "burned child dreads the fire," and after a gopher has once been nipped by a trap that failed to hold him he becomes more or less wary, and the trap must be set in a different way or poison must be employed to get him.

As stated elsewhere, trapping is a good method of combating gophers if the field to be cleared of the pest is small or if over a large area there are but a few scattered gopher tenants. If the landowner is vigilant, the career of any invader may with little trouble be ended by the use of the trap. The objections to trapping are that it is slower then poisoning and more expensive, particularly the latter, if one must hire somebody to do the work. While I have elsewhere in this bulletin presented objections to the bounty system as a public measure, I believe that money paid for gopher scalps by individual landowners is wisely expended. Give your boys or your neighbor's boys a chance to earn a little pocket money, and thus by expending dimes save dollars on your crops. Furthermore, as the number of gophers on your place diminishes raise the price per scalp now and then, so that the boys may be encouraged to complete the extermination. This is strictly a business proposition. No busy farmer need give much of his time to the work, but he will find that the average boy will get as much satisfaction out of earning money by trapping wild animals as he will from expending the same in the various channels known only to his tribe. Then, too, the farmer will have the satisfaction of knowing that the expense of freeing his premises of the pest has not been borne by the public treasury.

In the course of our experiments, covering a period of three seasons, several makes of special gopher traps have been thoroughly tested for efficiency, and the ordinary steel trap has been set in various ways with the hope of finding a best way. In the latter respect I cannot say that we have succeeded, for it does not seem to make much difference how one sets the steel trap; results will be about the same. These results, obtained by 100 tests of each of four or five different methods, are given in the table further on.

In trapping the location of the runway is determined in one of two ways: by prodding with a sharp stick on a line between two fresh hills of earth, or by digging into the mound itself until one strikes the short lateral. A sharpened broomstick, or a wagon rod, and a spade, are the best tools to use if one follows the first plan. In digging into the mound to the lateral a heavy plant trowel, with a strong shank, serves the purpose very well, and can be carried about in the hip pocket when not in use. A careful scrutiny of the mound will usually reveal the exact spot from which the dirt was thrown out and enable one to locate the lateral with very little digging.



A handy tool for use in setting traps.

Among the methods of setting the steel trap which suggested themselves to us, or were recommended by others, we tested five. As stated before, the per cent of catch did not vary greatly. The plan of digging into the lateral at the mound, pushing the trap back a little way and leaving everything open gave the poorest results. More of these traps were packed with earth and fewer caught and held the gopher than when set in any other way. Attracted by the flood of light which enters the burrow at the large opening the animal is pretty sure to come pushing a heavy load of dirt ahead of him. This clogs the trap at once. The plan of admitting a little light through a chink between the sods covering the opening into the burrow, or through a hole bored for that purpose in a board, demonstrated that the admission of any light at all is unnecessary and perhaps operates to reduce the catch. The gopher is not so likely to be pushing a load of dirt when he encounters the steel trap in the dark. As between covering the trap itself or leaving it uncovered, I should recommend the latter plan. In a series of 100 tests we carefully covered one trap in each case with tissue paper and fine earth and left the other exposed. The per cent of catch was so nearly the same that the slight difference in favor of the covered trap would not warrant the expense of extra time required to set the traps in this way. In fact, later experiments, performed when the ground was wet from recent rains, gave the poorer result for the covered trap, on account of the jaws clogging. As the gopher in his underground tunnels must be guided entirely by the sense of smell and of feeling, there could be no particular advantage in concealing the trap with a thin covering of earth. This practice has no doubt arisen from similar methods employed in trapping animals that live above ground.

It seems to me, therefore, that the most practical and efficient method of using the steel trap is to simply open the burrow at some point, introduce the trap, and completely cover the opening you make with sods, a bunch of hay, or perhaps a board—anything that is convenient and will exclude all light. Vary the method of setting the trap if the animal keeps filling it with earth. Placing the trap vertically in the runway, with jaws down, will sometimes give good results. We have never tried baited traps of any sort. I believe, however, from the evidence of a few experiments, that one may increase the per cent of catch by covering the opening above the trap with freshly cut alfalfa.

Traps designed especially for the pocket gopher have the advantage, over the steel trap, of being more easily and quickly set and of killing the animals at once instead of holding them by the leg for hours. Some of them also have given us a higher per cent of catch than the steel trap. Of the five different patterns we have tested, all are built on pretty much the same lines. They are intended to be set at the end of a lateral, and are so constructed as to throw when the gopher pushes a load of earth against the trigger. A choker or a pair of sharp prongs does the rest. In setting any of these traps a ray of light must be admitted to the burrow through a small opening, so as to attract the attention of the gopher and cause him to come with a load of earth to stop up the hole. The trigger in any such special trap should be about three inches beyond the choker, so that when the former is tripped by pressure of the earth the animal will have his neck well in the noose.

The "California" gopher trap and the "O. K." gopher trap are almost identical in appearance and design. Both are easily and quickly set, and good results are obtainable by the use of either one. Each consists of a small box with one end open for the entrance of the gopher's head. At the opposite end of the box a small hole is bored to admit a ray of light. The box, when the trap is set, practically forms a continuation of the burrow. It should be placed with the open end close up to the opening into the lateral and the line of contact between trap and lateral sealed with a few handfuls of earth so that no light may reach the burrow except through the small hole in the end of the box. The trigger is skeleton in form so as not to obstruct this light, and depends vertically from the center of the box.

The "Out O' Sight" gopher trap is built like the "California," except that the sides and end of the box have been omitted—simply the roof is left for the attachment of the working parts. This trap is to be set in the same manner as the two just described, but one end has to be supported by means of a small stick laid across the opening into the burrow and sods must be used to exclude all light, except the ray which is to attract the attention of the gopher. Plainly the disadvantage in the use of this trap is in the greater length of time required to set it.

The "Newhouse" gopher trap is entirely of steel. It is arranged to trip in the same way as the others, but instead of a choker it has three sharp prongs which strike down into the neck of the animal. It is the least efficient of all of the makes of special gopher traps we have tried. If properly set it must be supported by a stick at one end, and so covered by sods as to leave only a small chink open. It is so light that a gopher coming with his load will upset it oftener than spring it. The small size of the trap also permits it to be drawn back into the burrow if the animal is caught. In this way we lost half of our traps the first week of our experiments. If used at all they should be secured with chain and stake. A few experiments seem to indicate that this trap gives much better results when used in the smaller burrows of the plains pocket gopher.

The "Hooker" trap is one of the best of the special devices for catching the pocket gopher. In design and mechanical working it is much like the "California" and the "O. K." traps, but it possesses the special advantage of having its shield or box made of galvanized iron, instead of wood as in the others. The wooden traps sometimes warp badly from contact with the damp earth and we have had several gnawed to pieces by gophers held fast in such a way as to escape choking.

STEEL TRAP TESTS.

Conditions under which traps were set.	Number traps set.	Number disturbed.	Number gophers caught.	Per cent catch.
Entrance to burrow entirely darkened; trap covered with tissue paper and fine earth	100	77	28	36+
Entrance to burrow entirely darkened; trap left uncovered	100	75	25	33+
Entrance to burrow left wide open; trap not covered	100	81	17	21
Entrance to burrow covered by board having a small hole for the admission of light; trap not covered	100	66	18	27+

In all cases the light No. 0 steel traps were used. They were placed horizontally in the runways and were not baited. The per cent catch is based on the number of traps disturbed, including those that caught and held the gopher. The tests were made mainly in the spring and fall months.

SPECIAL TRAP TESTS.

Trade name of trap.	Number traps set.	Number disturbed.	Number gophers caught.	Per cent catch.
California Gopher Trap	100	71	26	36+
Newhouse Gopher Trap	100	72	14	19+
Out O' Sight Gopher Trap	100	82	36	43+
Newhouse Trap modified by addition of sheet-iron shield and skeleton trigger	100	69	26	37+
Ordinary steel trap set various ways	100	75	23	30+

NOTE.—At the time these tests were made the Hooker trap was not on the market, or at least had not been brought to our notice.

The best time to trap is in the spring and fall, particularly in October and November. At those seasons the gophers are especially active in extending their burrows or storing up food. It will generally pay to run the traps twice a day—in the morning and as late as practicable in the evening. Experience has proven that one may sometimes catch a second gopher by resetting at the same opening where a gopher has already been trapped, but is scarcely worth while to make the attempt unless one notices after trapping the first animal that the opening into the burrow has been filled again from the inside.

Shooting; Trap Guns.—If one has the time and inclination to do a little shooting, he can kill quite a few gophers with the shotgun. The best time for shooting is early in the morning or late in the evening, when the animals are pushing out their loads of earth. Open holes can then usually be found, but if not one can easily open a few burrows and keep watch of those which are being filled up again. It requires quick work on the part of the sportsman to bag his game, for all that can usually be seen is a little spurt of earth and perhaps a nose. In a few cases that came under my notice a bag of ten or a dozen gophers was made in a single evening or morning.

A trap gun so arranged as to be discharged by the act of the gopher in pushing against an obstruction in his burrow has been recommended by at least two of the experiment stations. The objection to this recommendation lies in the first cost of the mechanism and the amount of time required to visit and reset the gun each time it has been discharged.

SUMMARY.

1. The prairie pocket gopher is most abundant in the central and northeastern parts of the state, particularly in the region drained by the Kansas river and the lower courses of its main tributaries. The plains pocket gopher is found in more scattering numbers in the western third of the state and down the Arkansas valley to some distance east of the great bend. Southeastern Kansas is comparatively free from gophers.
2. The gopher digs extensive runways in the subsoil of wild lands and cultivated fields, piling the excavated earth in mounds on the surface. These runways have no exit above ground. A single animal will throw up several mounds a day for weeks at a time. A gopher spends his entire time in his underground burrow.
3. Gophers breed in the late winter and early spring. Pregnant females may be found from January to May, but the young are nearly all born in March and April. There is but one brood a year. The number of young varies from three to six, and averages a little more than four.

4. The natural food of the pocket gopher consists of the fleshy roots it encounters in extending its runways, with the addition of some succulent vegetation drawn down into the burrow from above ground. Some food is stored in underground chambers for winter use.

5. Gophers are active at all seasons, but particularly so in the fall and spring. They do not hibernate. They throw up mounds any day in the year when the ground is not frozen too hard for mining operations.

6. The pocket gopher, by reason of his secluded life, has but few natural enemies. Bull-snakes, weasels, owls, cats and striped skunks destroy some of them, but cannot be depended upon to keep them in check.

7. Cultivated crops are damaged by the attacks of gophers on their root systems and by being covered with excavated earth. Much loss to the farmer also occurs through the obstruction to harvesting operations occasioned by the presence of the mounds. The alfalfa grower has the most ground for complaint, but nurserymen, orchardists, truckers and potato farmers also suffer heavy losses.

8. We have in Kansas two laws affecting the gopher; one a compulsory extermination law, the other a bounty law. The compulsory extermination law has two weak points, which render it practically inoperative. The bounty law has been tried and found wanting. Better results can be obtained, and at much less cost, by the plan of furnishing poison at the expense of the county or township.

9. Poisoning is the best method of combating the pocket gopher we have so far discovered. Trapping is effective, but slower than poisoning. Fumigation does not give good results, and therefore we do not recommend it. The poisoned baits that have given us the best results are soaked corn or finely chopped sweet potatoes treated with a syrup prepared by the Experiment Station. Raisins, prunes and pieces of apple, potato and sweet potato into which crystals of strychnine have been inserted also make excellent baits, but require much more time in preparation than the corn or sweet potato baits.

10. Extermination of the pocket gopher in Kansas is not to be looked for, but communities may be entirely freed from the pest by persistent and concerted action on the part of landowners.

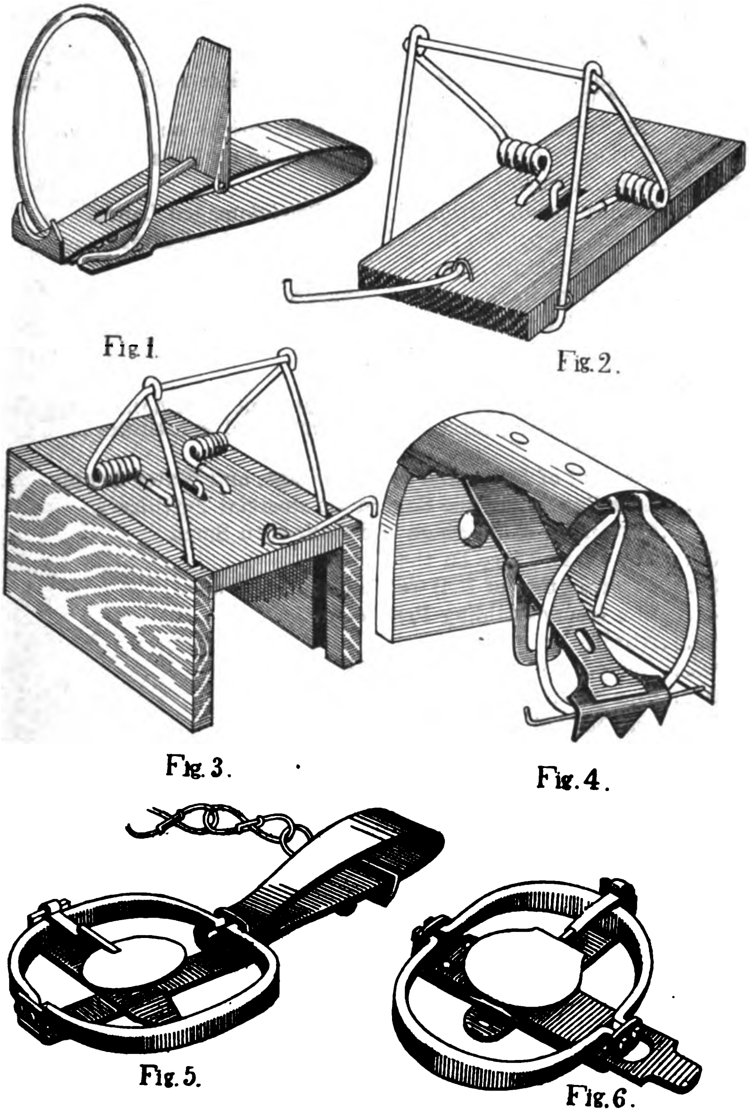


Fig. 1.

Fig. 2.

Fig. 3.

Fig. 4.

Fig. 5.

Fig. 6.

Fig. 1, Newhouse gopher trap. Fig. 2, Out O' Sight gopher trap. Fig. 3, California gopher trap. Fig. 4. Newhouse trap as modified for use at this Station. Fig. 5, steel trap No. 0. Fig. 6, the steel jump trap.

THE FOLLOWING BULLETINS

ARE AVAILABLE FOR DISTRIBUTION TO THOSE RESIDENTS OF KANSAS WHO MAY DESIRE THEM.

No. 12....Preliminary Experiments with Fungicides for Stinking Smut of Wheat.
No. 15....Additional Experiments and Observations on Oat Smut.
No. 52....Kansas Weeds—Preliminary Circular on Distribution.
No. 120....Tests of Forest Trees.
No. 121....Treatment and Utilization of Flood-damaged Lands.
No. 129....Kansas Mammals in their Relation to Agriculture.
No. 136....Press Bulletins Nos. 125-151.
No. 137....Variations in the Test of Separator Cream.
No. 138....Effect of Bacteria in Wash-water of Butter.
No. 139....The Study of Corn.
No. 140....Milking Machines.
No. 141....Commercial Seeds of Brome-grass and of English and Kentucky Blue-grasses: Adulterants and Substitutes and their Detection.
No. 143....Disposal of Dairy and Farm Sewage, and Water Supply.
No. 148....Law Regulating the Sale of Commercial Fertilizers.
No. 149....Prevention of Sorghum and Kafir-corn Smut.
No. 150....The Hen's Place on the Farm.
No. 153....Deterioration of Red Texas Oats in Kansas.
No. 154....The Mound-building Prairie Ant.
No. 155....Alfalfa.
No. 158....Analyses of Registered Feeding-stuffs.
No. 160....Cow-peas.
No. 162....The Marketing of Eggs.
No. 163....Hog Cholera and Vaccination.
No. 164....The Selection and Feeding of Laying Hens.
No. 165....Forest Conditions in Central and Western Kansas.
No. 167....A Quantitative Method for the Determination of Hardness in Wheat.
No. 168....The Common Mole.
No. 169....Fertilizers and their Use.
No. 170....Breeding for Type of Kernels in Wheat.
No. 171....Studies on Hog Cholera and Preventive Treatment.

Circular No. 1....Treating Seed-corn to Protect it from Burrowing Animals.
Circular No. 2....Preparing Land for Winter Wheat.
Circular No. 3....Improved Seed Wheat.
Circular No. 4....Prairie Dog Situation.
Circular No. 5....Chinch Bug.
Circular No. 6....Variety Tests.
Circular No. 7....Corn Ear-worm.
Circular No. 8....Investigation of the Vitality of Kansas Seed-corn.
Circular No. 9....Rabies—Hydrophobia.
Circular No. 10....Provisions of the State Forest Law.

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Kansas State Agricultural College.

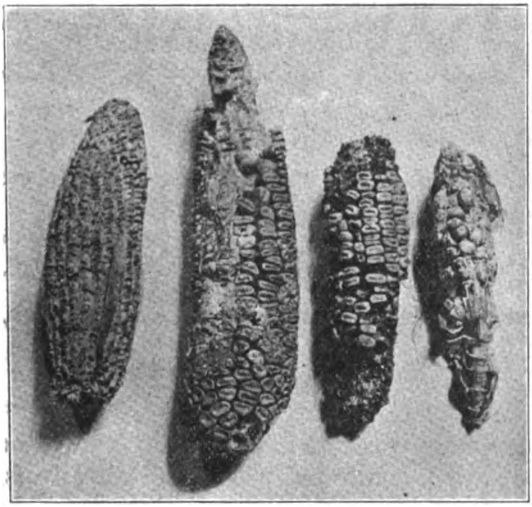
EXPERIMENT STATION.—Bulletin 173.

ED. H. WEBSTER, *Director.*

FARM BULLETIN.

Department of Veterinary Science.

F. S. SCHOENLEBER, *Veterinarian in Charge.*



Corn Damaged by Mold.

Meningo-Encephalitis.

(BLIND STAGGERS.)

BY

THOS. P. HASLAM,

Assistant in Corn Mold Investigations.

MANHATTAN, KAN.
SEPTEMBER, 1910.
3664

DEPARTMENT OF VETERINARY SCIENCE.

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Dr. K. W. STOUDER	Assistant Professor, in Charge of Surgery and Clinic.
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THOS. P. HASLAM, M. S.	Assistant in Corn Mold Investigations.

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Special lines of investigation are taken up from time to time, as necessity demands.

Bulletins are issued on these subjects, which, with the bulletins of other departments of the Station, may be obtained free of charge by residents of the state, by addressing the Director, Experiment Station, Manhattan, Kan.

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Meningo-Encephalitis (*Blind Staggers*).

By Thomas P. Haslam,
Assistant, Corn Mold Investigations.

This disease (*1*), commonly known as staggers, blind staggers, sleepy staggers and mad staggers, has occurred, in outbreaks of greater or less severity, in many sections of the United States. Among a large number of states in which losses have occurred, Kansas, Texas, Louisiana, North Carolina, Delaware and Arkansas have experienced the most trouble.

Previous to the establishment of the Veterinary Department of this Experiment Station we have no written record of the trouble in this state, but various farmers and veterinarians seem to have encountered cases at a very early date. In 1891, soon after assuming his duties as veterinarian of this Station, Doctor Mayo investigated a severe outbreak that extended over almost the entire state. He states that owing to the dry weather the corn crop was almost a total failure, and that a certain green mold, *Aspergillus glaucus*, had badly damaged the small amount of corn that was grown. To this mold he attributed the death of the horses. In 1902, and again in 1906, there were severe outbreaks in various portions of the state. Besides these general outbreaks there seems to be a continual loss of horses from staggers in any locality in which much corn of an inferior grade is fed.

During the outbreak of 1906 the writer began an investigation of this trouble under the direction of Dr. F. S. Schoenleber, veterinarian of the Kansas Experiment Station. Examination of corn from the seat of the outbreak failed to show the presence of *Aspergillus glaucus*, but did show three molds: *Mucor rhizopodoformis*, *Rhizopus nigricans*, and *Fusarium* sp. Accordingly an investigation of the properties of these molds was carried out by the writer for the next two years, and continued by Dr. P. J. Meenen during the years 1908 and 1909. Owing to insufficient funds progress was slow until July, 1909,

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Note.—We are indebted to Dr. M. A. Barber of the Kansas University Medical School for many valuable suggestions, and to Dr. C. E. Basseler of Greensburg and Dr. F. O. Chase of Haviland, Kansas, for much aid in our field investigations.

when the writer was employed to devote his entire time to research work upon this subject.

In addition to the results recorded in this bulletin, there has accumulated a large amount of material of a purely scientific nature which will be published later. While the exact cause of the trouble has not as yet been discovered, there seems to be no doubt that it can be produced by immature ears of corn infected by the molds described later in this bulletin. Experiments are being carried out at present to determine whether such immature ears free from molds will produce the same results, or whether these molds themselves produce a poison capable of causing the staggers. When these experiments have been completed, several points which are not as yet clear will probably be decided. While in this state we have few authentic records of cases occurring when the horses have not been fed on corn, yet in other states severe losses of horses have occurred when the grass in the pastures becomes moldy. Since the disease in this state has occurred almost exclusively where the horses have been fed upon this immature moldy corn, these results are published as a preliminary report, at this time, in order to prevent further loss of horses from this cause.

The work has been done under the direction of Dr. F. S. Schoenleber, veterinarian of this Station. Much valuable assistance has been given by Dr. L. W. Goss, pathologist of this department; the autopsies on all of the cases recorded in this bulletin having been held by him. Martin Dupray has been for the past year a constant and efficient aid in these investigations, and the analyses of the moldy feed were largely carried out by him. Cultures of many of the molds encountered in this work have been sent to Dr. Chas. Thom, of Storrs, Conn., who has given much valuable aid in their identification.

SUMMARY.

The contents of this bulletin may be briefly summarized as follows:

1. Feeding horses upon immature corn badly infected with molds and worm dirt, with its accompanying bacteria, produces typical cases of staggers.
2. The extract of such corn is rapidly fatal to rabbits.
3. *Aspergillus flavus, Aspergillus niger* and *Rhizopus nigricans* have been found abundantly on the corn only in localities which lose horses from staggers.

4. Corn containing any molds should be thoroughly cleaned or "floated" before feeding.

5. Mixing corn with bran and oats seems to lessen the danger.

6. Treatment to be effective must be begun early.

7. This department will analyze and report upon samples of corn free of charge. About one peck is needed, which should be sent, prepaid, to the Veterinary department of the Kansas State Agricultural College.

DIAGNOSING THE TROUBLE.

During the course of these investigations it was found that in some localities cases which were reported as staggers were in reality typical cases of parasitism produced in horses by the palisade worm (*Sclerostoma equinum,* or *Strongylus armatus*) in the intestines and blood vessels, the error arising from the similarity of some of the symptoms of the two diseases. Those familiar with the course of either disease rarely make this mistake. To avoid this error some of the symptoms seen in each trouble are given below in parallel columns:

STAGGERS.	PALISADE WORM.
Previous history: Animal has been running in a stalk field or eating wormy or moldy corn, smutty grass, or decayed food.	*Previous history:* Animal has been in pasture containing stagnant water, or has been watered from a dirty trough.
Beginning: If the animal has been carefully watched some loss of appetite may have been noticed, otherwise the first symptoms observed will be that the horse stumbles over ordinary low objects. If the animal has not been worked these symptoms may be overlooked. Eyes either dull or excited.	*Beginning:* The first symptoms may be any one or a combination of the following: Colic, restlessness, or weakness of the back.
Development: A few hours after showing the above symptoms the horse will either develop (*a*) "mad staggers" or (*b*) "sleepy staggers," or a combination of the two. (*a*) *Mad staggers:* The horse becomes very violent, runs through fences, into trees, machinery, etc., usually traveling	*Development:* The animal is usually restless, falling or throwing itself down and getting up again in a few minutes. When no longer able to get up it struggles violently at variable intervals and paws so vigorously that it ultimately digs a half circle around itself in the dirt. Often it bites at its sides.

STAGGERS.	PALISADE WORM.
in circles. It cannot be driven or led through the barn door without running against one side. After a few hours the horse becomes quiet and the symptoms resemble those of sleepy staggers. (2) *Sleepy staggers:* The patient, either with or without having shown the above symptoms, becomes stupid and sleepy, leans against the side of the barn, or pushes against the manger; stands with legs spread apart in a characteristic manner; refuses to be led; but some cases can be made to go backwards.	
Treatment: If the intestines can be emptied and excretion stimulated soon after the first symptoms are noticed many of the cases will recover.	*Treatment:* After the symptoms appear treatment cannot greatly alter the course of the disease. The parasites should be removed from the intestines.
Recovery: Few cases recover without treatment.	*Recovery:* It is not unusual for cases to recover without treatment if the parasite does not invade the circulation to any great extent.
Duration: Usually from six or eight hours to days.	*Duration:* Some cases die almost instantly, others show symptoms for months.
Post-mortem: Congestion of the intestines, brain and its coverings (meninges), are usually observed. (Some writers report softened areas in the brain.)	*Post-mortem:* The finding of large numbers of palisade worms in a part of the large intestine (cæcum), or enlargements (aneurisms) of the anterior mesenteric or other arteries.

RELATION TO CORNSTALK DISEASE.

The observations of this department have not been sufficiently extensive to determine the relation between staggers and the so-called cornstalk disease. The latter is the name popularly applied to many disorders of the digestive tract in cattle and horses, some of which are clearly not the result of any poison or toxin. It seems that neither the seasons nor the localities in which many cattle have died in the stalk fields coincide with those in which severe outbreaks of staggers in horses have occurred.

RELATION TO PELLAGRA.

At the first pellagra conference, held in Columbia, S. C. (*2*), Doctor Wood pointed out the similarity of pellagra in man and staggers in the horse, and expressed the opinion that the diseases are identical. A careful review of the literature, and feeding experiments with various animals carried out by this Station, have indicated that only man and the horse develop a recognized set of nervous symptoms from eating moldy food. In other animals, diseases of the stomach and intestines sometimes result and death occasionally follows from diarrhœa and inflammation of the bowels. This is particularly true in the case of white mice, guinea pigs and rabbits. These experimental results agree with the practical observations of many farmers and stockmen. Almost all farmers, even in districts suffering from staggers, feed the moldiest portions of the corn to their hogs, apparently without injurious results. Some feeders exercise no care whatever in selecting the feed for their cattle, or, if they do, they select the best portions for their horses and feed the refuse corn to the cattle. As yet few reports of loss from feeding cattle moldy feed have reached us, though the practice can scarcely be recommended. If, as seems to be the case, man and the horse are peculiarly affected by moldy feed, then experiments upon horses have the greatest significance in the investigation of the very obscure trouble in man known as pellagra. The positive results of the feeding experiments recorded below add strength to the theory that pellagra may be caused by an almost exclusive diet of unsound or immature Indian corn.

CAUSE OF STAGGERS.

Several publications by various experiment stations have dealt with this disease. Their results have been for the most part negative. Foreign investigators have likewise obtained almost uniformly negative results when feeding horses, cattle sheep or goats upon moldy feed. But Doctor Klimmer (*3*), of Berlin, one of the leading German veterinary authorities, in commenting upon these negative results, issues a warning against the use of such feed, saying that the frequent losses of stock following the use of moldy feed renders it very probable that the experiments were not sufficiently extensive from which to draw conclusions.

While a large number of experiments have been conducted by the Veterinary Department of the Kansas Experiment Station during the past three years, only a brief summary of the work will be presented here, leaving a full report until the experiments now in progress are completed.

MOLDS ATTACKING KANSAS CORN.

Black cottony mold (*Mucor rhizopodoformis*), yellow-green dusty mold (*Aspergillus flavus*), grayish cottony mold (*Rhizopus nigricans*), and black dusty mold (*Aspergillus niger*), occur on the corn in great abundance under certain conditions. They have all been shown to produce more or less poison, and until more evidence has accumulated, corn infected with any of the above molds should not be fed to horses. These three molds occur abundantly upon the corn in districts losing horses from staggers, but are rarely found upon the corn where staggers does not exist. They do not seem to possess the power to attack uninjured ears of corn, but follow some injury, usually that produced by the corn-ear worm. If the ear is a thrifty, vigorous one, the growth of the mold will probably confine itself to the vicinity of the injured grains. But if, as in dry seasons, or because of poor soil, the corn is stunted, then these molds are able to cover the entire ear. This is especially true if the dry spell which partially kills the corn is followed by a warm wet spell, which favors the growth of the mold.

EXPERIMENTS WITH MOLDS AND BACTERIA GROWN IN THE LABORATORY.

Rabbits, guinea pigs and horses have been fed, for periods of about one month each, upon food in which was mixed a liberal supply of mold, without results. The molds employed were *Aspergillus flavus, Aspergillus niger* and *Mucor rhizopodoformis*. The latter mold kills rabbits in three days when injected into their veins, but three rabbits were maintained for nearly a month upon feed which was black with this mold without noticeable injury.

At the present time this department is feeding horses upon molds grown in the laboratory, and the result will tend to show whether the molds or the immature corn itself is the cause of the trouble.

Of the bacteria found upon the corn, one species (belonging to the *Ærogenes* group) is usually fatal to horses and rabbits when injected into their veins. It does not develop in the blood and often entirely disappears from it if the animal does not die for some time. Bacteria which have been heated to boiling for half an hour are just as injurious as the living ones. This bacterium is always present in the excrement of the corn-ear worm, and exists in large quantities in the so-called worm dust of corn.

FEEDING EXPERIMENTS WITH MOLDY CORN.

Analysis of Material Fed.

The moldiest corn available in the state was obtained and graded as follows: The length, average diameter of each ear, and number of square inches damaged by each species of mold, were measured, and from the data thus obtained the average content, for the entire experiment, of each mold given below, was calculated:

Total area damaged by all molds	24.54	per cent.
Area damaged by *Aspergillus flavus*	1.58	" "
" " by *Aspergillus niger*	3.64	" "
" " by *Fusarium* Sp.	5.92	" "
" " by *Penicillium glaucum*	4.15	" "
" " by *Diplodia zea*	6.15	" "
" " by *Rhizopus nigricans*	2.85	" "
" " by other molds	0.254	" "

Toward the close of the experiment some of the corn was ground and analysis made by the plate method. This gave about fifty million bacteria per gram of the dry substance, thirty-three million of which were of the species producing the poison.

Analysis of this same sample by plating upon Pasteur agar and corn-extract agar gave the following results:

Total number mold spores per gram of corn	21,000,000
Number of *Aspergillus flavus* spores per gram	6,000,000
" of *Aspergillus niger* spores per gram	2,000,000
" of *Fusarium* Sp. spores per gram	12,000,000
" of *Penicillium glaucum* spores per gram	400,000
" of *Rhizopus nigricans* spores per gram	600,000

That only a small portion of the spores present were capable of germinating may be seen from the fact that, by the use of appropriate stains and special counting apparatus, the material could be shown to contain 292 million mold spores per gram. A gram of the ground corn is about the quantity of meal that will lie on the point of a large pocket knife.

Extracting the Poison.

After a series of preliminary experiments, in which alcohol, ether and water were employed, the following method was shown to give the best results: One hundred grams (¼ lb.) of the finely ground corn is mixed with 1000 cc. (1 qt.) of water and heated, with constant stirring, at 70 degrees centigrade (158° F.), for four hours, allowed to stand until it has settled and the somewhat cloudy liquid is siphoned off and concentrated at 70 degrees centigrade until it is evaporated to 30 cc. When this concentrated extract in quantities of 30 to 60 cc. is introduced into a rabbit's stomach, the animal dies in from one and one-half hours to two days. Similar tests of sound mature corn have given negative results. Unfinished experiments with pure molds and with immature corn have shown that the extracts of both are capable of producing death in a rabbit when introduced into its stomach.

Results of Feeding the Corn.

On November 8, horses Nos. 1, 2, 3, 5, 6 and 7 were placed upon a diet of this corn. From November 9 to 14, Nos. 2 and 3 received about one kilogram of ear corn (approximately 2½ lbs.) twice daily. All of the horses ate well and seemed in every way normal.

On November 14 a gradual increase was made and continued until Nos. 6 and 7 were receiving 1800 grams (approximately 4 lbs.) twice daily, and Nos. 1, 2, 3 and 5, 2200 grams (approximately 5 lbs.). About the 1st of December No. 7 lost its appetite, and December 12 was taken off the experiment. November 27 No. 4 was placed upon the same corn and the amount gradually increased to 2200 grams (approximately 5 lbs.) twice daily. On December 17, horse No. 6 was found dead at noon, having died apparently without a struggle. Postmortem showed congestion of the gastro-intestinal tract, but it was impossible to ascertain the cause of death. On the 21st of December, horse No. 1 developed a typical case of staggers. Horse No. 2 developed staggers on December 22, horse No. 3 on December 27, and horse No. 4, which was placed in the feeding experiment November 27, succumbed on January 14 with staggers. On January 13 horse No. 5 was used for another purpose because the supply of corn was exhausted.

Arranging these results in tabular form, we see that four-sevenths, or 57 per cent, of the number of horses started upon the experiment died of staggers after eating the corn forty to fifty days, and that four-fifths, or 80 per cent, of those which ate the corn for forty days or longer died. Most of the horses used in these experiments were aged animals.

No.	Date feeding commenced.	Date discontinued.	Days fed.	Remarks.
1	11– 9–'09	12–21–'09	41	Succumbed to staggers.
2	11– 9–'09	12–22–'09	43	" "
3	11– 9–'09	12–27–'09	50	" "
4	11–27–'09	1–14–'10	48	" "
5	11– 9–'09	1–13–'10	67	Appetite had been fairly good, but not equal to that of the other animals, and was removed from the experiment.
6	11– 9–'09	12– 7–'09	30	Found dead; cause of death not evident on post-mortem examination.
7	11– 9–'09	12–12–'09	35	Discontinued feeding because of poor appetite, probably due to bad teeth.

RECORD OF CASES.

The symptoms and post-mortem findings of these horses are given below:

Case No. 1.—On December 21, at 9 o'clock A. M., some difficulty was experienced in leading the horse to water, and the animal seemed quite nervous. At 9:30 A. M. the horse was trembling all over, could not be led or forced to move for some time, and when finally induced to move walked stiff-legged, going sidewise with a very unsteady gait, walking in a semicircle to the right, from the south to the north end of the barn. After a great deal of trouble the horse was finally placed in a box stall, where he leaned up against the side and kept bumping his head. At about 10 A. M. he went around the stall leaning against the wall all the way. He then began to show signs of great nervousness, exhibited violent symptoms for a few minutes and then floundered down. When down he was very violent, striking with his feet and throwing his head. He drew his head around and bit at his side for several minutes, and then made several unsuccessful attempts to rise, gnawed the ground a while, and then became quiet. Temperature at 10:15 A. M., 100.6 degrees. At 11 A. M. he was resting his nose on the ground, partly closing his nostrils; otherwise about the same as at 10:15 A. M. At noon he had changed his position in the stall by attempting to rise. He lay flat on his side part of the time and attempted to rise, but could not do so. Pulse 78, regular; temperature, 100.5. At 12:30 P. M. and at 1 P. M. was lying flat and quiet, but struggled when touched.

At 1:30 P. M. he had passed into a sleepy (comatose) condition, the only response to prodding being twitching and jerking of the muscles (exaggerated reflexes). This condition continued until death took place, at about 6:30 P. M. During the last few hours he breathed with violent flank convulsions and showed a marked jugular pulse. Post-mortem examination was held two hours after death.

Peritoneum: Slightly congested.

Small intestine, lymph glands and mesentery: Ecchymoses just under the peritoneum; mesentery slightly congested; lymph glands normal.

Large intestine and lymph glands: Ecchymoses on wall; contents normal.

Spleen: Slightly congested; hematoma on surface at central part.

Kidneys: Slightly congested.

Liver: Slightly congested.

Pleura: Small amount of organic exudate.

Lungs: Showed petechiæ upon surface.

Brain and meninges: Slightly congested.

Spinal cord and meninges: Slightly congested.

Other organs or parts: Normal.

Résumé of morbid changes: Indications of toxæmia.

Cultures were made from the blood and viscera as follows:

Material.	*Medium.*	*Results.*
3 cc. of blood from jugular vein a few minutes before death...	Nutrient bouillon	No bacteria developed.
3 cc. of heart blood 3½ hours after death...	Nutrient bouillon	No bacteria developed.

Portions of the various organs, about .5 cm. in diameter, were placed upon the surface of sterile agar in large test tubes, as follows:

Organ.	*Results.*
Spleen	No molds.
Liver	No molds.
Brain	*Aspergillus niger.*
Brain	No molds.

Case No. 2.—The first noteworthy symptoms were observed December 22, 1909, although two days previous the animal ate and drank very poorly, and on the 21st did not drink at all. At 1:30 P. M. the animal was found leaning against the side of the stall and showing marked paralysis of the muscles of the nose and neck. When disturbed he would turn in a circle to the left. Breathing was about normal, and the animal responded when spoken to sharply. The temperature was 100.5. The symptoms remained the same, refusing food and water on account of the paralyzed condition of the muscles of the mouth and throat, until December 25, when he was able to eat and drink a little; but again on the next day he was unable to eat or drink. Respiration still remained normal. Temperature 100.5. These symptoms continued until December 31, the animal having stood for hours at a time leaning against the side of the stall, or pressing its head and nose against the side of the barn. Death occurred without additional noteworthy symptoms.

Post-mortem was held a few hours after death and showed conditions exactly similar to those described in the cases of No. 1 and No. 3. Cultures were made in bouillon and pieces of the various organs were removed, with all the usual precautions, and placed on the surface of nutrient agar in large tubes, with results as follows:

Source of material.	*Medium.*	*Results.*
5 cc. blood from heart,	2 tubes of nutrient bouillon	No bacteria after twelve days anærobic incubation.
Portion of spleen.....	2 tubes of nutrient agar,	No mold.
Portion of lymph glands	2 tubes of nutrient agar,	One tube developed *Aspergillus flavus.*
Portion of brain	8 tubes of nutrient agar,	One tube developed small *Mucor.*
Portion of lung	2 tubes of nutrient agar,	One tube showed a *Mucor,* the other *Aspergillus flavus* and an unknown white mold.
Portion of liver	2 tubes of nutrient agar,	No mold present.

Case No. 3.—On the evening of December 25 it was noticed that he did not eat all of his feed. On the next day, at 8 A. M., he became violent and would pay no attention to his feed. An attempt was made to remove him to the hospital but great difficulty was experienced in doing so. He would not lead, and was finally backed out of the barn, when he fell to the ground, and after numerous unsuccessful attempts to rise finally regained his feet. When an attempt was made to lead him he fell to the ground again and experienced a similar difficulty in regaining his feet. He was then backed to the hospital, a distance of perhaps ten rods, and placed in a box stall. He now showed great nervous excitement and constantly leaned against the side of the stall. Temperature 100.7.

At noon, spells of restlessness alternated with periods of quiet, in which he would lean against the wall of the stall. This condition lasted throughout the afternoon. Toward evening he began stumbling blindly about the stall, butting with great force into everything that came in his way. He finally was allowed to get out, when he would walk rapidly and unsteadily in a large circle to the left, running into a fence several times, and finally falling down. He remained in a passive condition for about ten minutes, after which he rose to his feet. At this time there was only one attendant with him, and two hours were spent in an attempt to get the animal to the hospital again, during which he had spells of restlessness in which he walked in circles, and spells of rest in which he leaned against the fence. The active periods lasted for about ten minutes and the periods of rest for about two to three minutes each. At 11:30 P. M., after a number of unsuccessful attempts to lead him, owing to his tendency to turn to the left, he was backed into the hospital. During the remainder of the night he showed the alternate periods of rest and excitement. At 6 A. M. he went down, unable to rise again. During the latter part of the night he showed paralysis of the muscles on the left side of the tail. When he was down he was very violent, struggling considerably. At 8:30 A. M. his temperature was 103.

Death occurred that afternoon at 4:15, after about thirty hours of illness; violent struggling, groaning and gritting of teeth continuing to the end. Post-mortem was held in a few hours, with the following findings:

Subcutis: Some bruises.

Small intestine: Slight congestion; ecchymoses, size of a pea, on wall.

Mesentery: Yellowish red.

Large intestine, with contents and lymph glands: Contents normal; a few ecchymoses as on small intestine.

Kidneys: Slightly congested.

Mouth cavity wounded.

Pleura: Congested; fluid contents of the pleural cavity slightly increased.

Lungs: Some congestion.

Pericardium: Slightly congested.

Heart blood vessels and contents: Normal, except ten to twelve palisade worms in the mesenteric artery.

Brain and meninges: Congested.

Spinal cord and meninges: Normal.

Résumé of morbid changes: Indications of toxæmia.

Portions of the tissue were placed in test tubes on sterile agar with the following results:

Organ.	*Result.*
Lung	*A. flavus* and a *Mucor.*
Lung	Four separate colonies of *Aspergillus,* also an undetermined white fungus.
Spleen	No mold.
Spleen	No mold.
Spleen	No mold.
Liver	No mold.
Liver	No mold.
Nodule on intestine,	No mold.
Nodule on intestine,	No mold.
Left cerebrum	No mold.
Left cerebrum	No mold.
Left cerebrum	No mold.
Left cerebrum	No mold.
Left cerebrum	No mold.
Cerebellum	No mold.
Cerebellum	No mold.
Kidney	No mold.

Except in the case of the specimens from the lung and spleen, an instrument was employed which was made by grinding a glass tube about one centimeter on the emery wheel to resemble a cork borer. A piston was made by wrapping a wooden rod with cotton. The entire instrument was wrapped in paper and sterilized by steam at fifteen pounds pressure With these tubes, cylinders of tissue were readily taken from the brain and placed in sterile test tubes. In the other organs the following method was employed:

After searing an area about six inches in diameter, the tube is held at right angles to the organ and by means of a rotary motion is pushed deeply into the tissue. The tube is then inclined until it is almost parallel to the surface of the organ and pushed in for two or three inches. By still further inclining the tube and pushing, the cutting edge will penetrate the sterile surface of the organ, two or three inches from the point of entrance. Still holding the tube parallel to the surface and pulling upwards the tissue between the two points is torn and the tube freed. The cylinder of tissue contained within the glass tube is pushed out directly into a sterile tube with the piston.

Cultures on bouillon were made from the heart blood and viscera as follows:

Material.	*Medium.*	*Results.*
4 cc. blood from jugular just before death	Nutrient bouillon	No bacteria.
Heart blood, 5 cc. taken 3 hours after death,	Nutrient bouillon	No bacteria.
Fluid from ventricle of brain	No medium added	Remained clear and showed no organisms upon microscopic examination.

Case No. 4.—Was fed from November 27 to January 14, when at about 10 A. M. it was noticed that the animal was suffering from severe nervous excitement. According to the report of the hospital attendant, when he attempted to lead her from the stall she became very violent and lunged about, striking the sides of the stall with great force and experiencing much difficulty in getting through the door. When outside of the barn, the ground being very icy, she slipped and fell and lay struggling violently. After several unsuccessful attempts to help the animal to her feet, owing to the extremely icy condition of the ground, she was placed on a sled and taken to the hospital. About two hours was consumed in this, during which she struggled constantly and frequently struck her head against the ice with great force. When she reached the hospital she was unconscious and died almost immediately. The post-mortem appearances did not differ from those already described.

In the culture tests special emphasis was placed on the search for a bacterium, and a number of anærobic cultures were made.

Source of material.	*Medium.*	*Results.*
5 cc. heart blood......	Nutrient bouillon.....	No bacteria.
5 cc. heart blood......	Nutrient bouillon.....	No bacteria.
5 cc. heart blood......	Nutrient bouillon.....	No bacteria.
5 cc. heart blood......	Nutrient bouillon.....	No bacteria.

(The above tubes were incubated in an atmosphere of hydrogen over alkaline pyrogallic acid, and after a week were removed and examined microscopically.)

5 cc. heart blood......	No medium added.....	No bacteria.
5 cc. heart blood......	No medium added.....	No bacteria.
5 cc. heart blood......	No medium added.....	No bacteria.
5 cc. heart blood......	No medium added.....	No bacteria.
One loop of brain substance	Nutrient bouillon.....	No bacteria.
One loop of brain substance	Nutrient bouillon.....	No bacteria.
Two loops spleen......	Nutrient bouillon.....	No bacteria.
Two loops spleen......	Nutrient bouillon.....	No bacteria.

(The above four tubes were incubated anærobically.)

Spleen	Nutrient bouillon.....	No bacteria.
Spleen	Nutrient bouillon.....	No bacteria.
Brain	Nutrient bouillon.....	No bacteria.
Brain	Nutrient bouillon.....	No bacteria.
Liver	Nutrient bouillon.....	No bacteria.
Ventricular fluid	No medium added.....	No bacteria.

In the above, as in all other cases, plate cultures from the blood before and after death, and from the liver, kidneys, spleen and brain, on ordinary agar and on corn-extract agar failed to show any bacterium common to all cases. The plates usually remained entirely sterile. In some cases, especially those from the liver, kidneys and spleen, colonies developed, but they showed no uniformity.

Interpretation of Results.

From a practical point of view, the relation between corn and staggers has been quite thoroughly demonstrated. The question naturally arises, which of the micro-organisms present on the corn is the specific cause of the trouble, or whether a too exclusive corn diet (*4*) or the immature corn possesses the injurious properties. These questions must still remain open, but the indications are that the cause of the trouble is contained in the moldy portions, as sound corn from the same bin was fed to more than a dozen horses and mules for months without producing any disorder. The assumption that the symptoms were caused by a soluble poison, and not by the parasitic growth of the micro-organisms in the tissues of the horse, is supported not only by the fact that extensive cultural tests fail to show the presence of any bacteria or molds, but also that experiments now in progress have demonstrated the presence of poisons in this corn.

Dr. Carlo Ceni, of Italy, and his pupils report (*5*) that the molds are capable of producing poisons, but only at certain seasons of the year, and that in the winter as well as in the middle of the summer they are entirely inactive.

Another fact of great interest has been developed by Dr. M. Otto, of Germany, that while the extracts of two species of *Aspergillus fumigatus* obtained from Italy are very marked poisons, those from the same kind of molds growing in Germany possess little or no poisonous properties. The influence of the time of the year and the locality in which the molds grew may perhaps explain why loss of stock does not always follow the use of moldy feed and why pellagra has not always been found in corn-growing districts.

PREVENTION AND CURE.

Veterinarians accustomed to treating this trouble usually cure a small majority of the cases treated if the treatment is begun before the disease has progressed very far. The most successful line of treatment seems to consist in the subcutaneous administration of arecoline or eserine and pilocarpine, followed by a good antiferment, and perhaps also an aloes bolus. It is very evident that the best means of combating this disorder consists in prevention. No unsound corn should be fed to horses. If it is necessary to feed a poor grade of corn, it should be shelled and thoroughly cleaned with a fanning mill. Very good results have been obtained by the so-called floating of corn before feeding, which consists in pouring it into water. The moldy grains, being lighter, rise to the surface and may be skimmed off. Good results are reported by some who have ground the well-cleaned corn and mixed it with equal parts of bran and oats.

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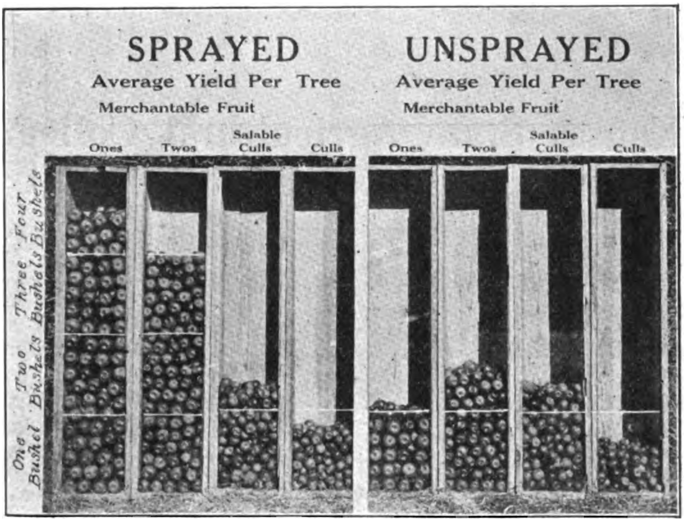
Kansas State Agricultural College

EXPERIMENT STATION.—Bulletin 174

ED. H. WEBSTER, *Director*

FARM BULLETIN



Results of spraying Jonathans. Average of lime-sulphur sprayed tree as compared with unsprayed tree.

Horticultural Department

ALBERT DICKENS, *Horticulturist in Charge*

AND

Entomology and Zoology Department

T. J. HEADLEE, *Entomologist and Zoölogist in Charge*

Spraying the Apple Orchard

By ALBERT DICKENS and T. J. HEADLEE

MANHATTAN, KANSAS
JANUARY, 1911

Kansas State Agricultural College

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Summary.

1. Commercial results from seven widely separated orchards, including both commercial and home types and composed of the varieties of apples recognized as standard in Kansas, carefully sprayed show an average gain of four bushels in actual yield of merchantable fruit per tree, or 37 per cent compared with untreated parts of the same orchards.

2. Not only is the actual and relative amount of merchantable fruit materially increased, but the average percentage of number 1's and number 2's, which are the high-priced grades, is also increased by 15 per cent and 6.6 per cent, respectively.

3. The average net profit from spraying is shown to be $1.62 per tree, or $97.20 per acre when the fruit is sold as "orchard run," and to be almost doubled if properly graded and marketed.

4. All seriously injurious insects and fungous diseases have been markedly reduced and most of them have been made almost negligible.

5. Prepared lime-sulphur plus arsenate of lead has produced the best results on apples subject to Bordeaux injury and nearly free from apple blotch, while Bordeaux mixture plus arsenate of lead gave best results on varieties attacked by apple blotch.

Printing Department
Kansas State Agricultural College
Manhattan, Kan.

K
Department
of Printing

Spraying the Apple Orchard.[1]

Introduction.

OBJECTS AND AIMS.

Kansas has a large but much neglected resource in her apple orchards. For every year of the past twenty[2] or more she has had over five million trees in bearing, reaching in 1899 more than seven and one-half millions. In the "bumper" apple year of 1906 the State-wide yield was only 6,378,008 bushels, or a little less than one bushel per bearing tree. The figures of State apple yield, which are available only since 1904, show a complete failure in 1907, and an average yield for five years of three and one-half million bushels, or a little more than one-half bushel per tree in bearing during the same period.

Many factors have contributed to bring about neglect of our apple orchards. Late frosts have year after year prevented the setting of much of the fruit, and the "worms" and fungi have rendered much of that which did set unfit for use.

It is for the purpose of showing the farmer and fruit grower how he may save that part of the crop which is usually sacrificed to insects and fungi that the Agricultural College has gone into the field and carried out this spraying. The results of the spraying have been uniformly good, the owners of the sprayed orchards are well pleased, and many of their neighbors are planning to use the spray pump next year. It is hoped that the orchard spraying of the past season is the beginning of a movement which may not end until the orchard resources of Kansas are properly developed and used.

ORGANIZATION BY MEANS OF WHICH THE WORK WAS DONE.

The eleven orchards selected for spraying were treated according to a definite schedule formulated by Mr. A. L. Quaintance, representing the Bureau of Entomology, and Mr. W. M. Scott, representing the Bureau of Plant Industry, of the United States Department of Agriculture, and Professors Dickens and Headlee and Mr. Holsinger, representing the Agricultural College. In all cases the work was done in coöperation with orchard owners—the owners hoping to get an increased crop and to learn how better to care for their orchards, while the Agricultural College and the government hoped to encourage the utilization of apple orchards in the production of better and more apples, the College hoping also to accumulate data to serve as a basis for a State-wide campaign for the proper utilization of our orchard resources.

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[1] This bulletin was planned by the authors, written by T. J. Headlee, and corrected and criticised by Albert Dickens. All illustrations, unless otherwise indicated, are original.

[2] The authors are indebted to Hon. Walter Wellhouse, secretary of the Kansas State Horticultural Society, for data on number of bearing trees for the past twenty years and the apple yield since 1904.

The work reported in this bulletin was begun by the Agricultural College purely as a demonstration, under the direction of and on the funds furnished by the Farmers' Institute and Extension Department, but it quickly became apparent that the situation was so unusually favorable for making a systematic test of spraying methods that the intended demonstration took on an experimental cast. By this new arrangement the Farmers' Institute and Extension Department furnished most of the funds and the services of Mr. Holsinger, while the Experiment Station furnished the balance of the funds and the services of Professors Dickens and Headlee, who were made responsible for the outcome of the test.

The orchard belonging to Mr. W. E. Boshcen[1], of Troy, Kansas, was handled by Mr. Holsinger alone. Six orchards, belonging to the State Insane Asylum, Mr. Godding, Mr. R. W. Coleman, Hon. F. H. Stannard, Mr. W. E. Barns, and Mr. John Coughlin, were handled by Messrs. Quaintance and Scott and their assistants, Mr. J. L. Stahl and Mr. Chas. H. Gable. The five remaining orchards, belonging to Snyder & Roediger, Mr. J. B. Fergus, Mr. J. T. Tredway, Mr. Isham Buckmaster, and Mrs. Woodworth, were treated by Professors Dickens and Headlee and Mr. Holsinger, Professor Headlee giving special attention to the Snyder & Roediger orchard, where headquarters was established. Mr. Rees Hillis was placed in immediate charge of the operations at the Snyder & Roediger plant, and was expected to help out at the other points. For a short time, Mr. Ralph Caldwell served as a coworker with Mr. Hillis, and during the balance of the season various graduate students of the Department of Horticulture, among whom may be mentioned Mr. Eugene Blair, Mr. Van Smith, Mr. J. R. Cooper, and Mr. D. E. Lewis, served in that capacity.

Late frost destroyed the fruit in the orchards of the State Asylum, Mr. Godding, Hon. F. H. Stannard and Mrs. Woodworth to such an extent that the treatment in these places had to be abandoned. Although injury was suffered in the other places, enough fruit set to render the continuance of the work worth while. In all, eight orchards were treated throughout the season and satisfactory results secured.

---

[1] The data from this orchard are not available and are not, therefore, included in this account.

It was the understanding reached during the conference that the results obtained by each coöperator should be furnished to the other coöperators, and that the publication should be joint or separate as seemed best, providing, in case of separate publication, proper credit should be given.

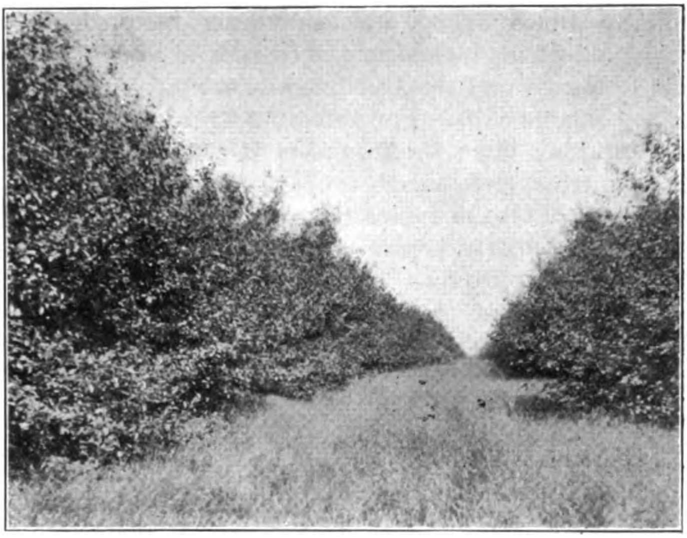

FIG. 1.—Between rows in the Jonathan block. Snyder & Roediger orchard.

Results.

RETURNS DURING THE PAST SEASON.

Five of these orchards might be classified as commercial, because they possessed enough of single varieties to form blocks of considerable size, while two were distinctly of the home type, being composed of a few trees of each of many varieties. In the home orchard of Mr. J. B. Fergus there were, according to the owner, thirty-three varieties. The general plan was so to select the demonstration blocks that three comparable plats could be secured, and to treat one with Bordeaux plus arsenate of lead, another with lime-sulphur plus arsenate of lead, and to leave the third untreated as a check. Of course local conditions compelled considerable deviation from the original plan.

With the exception of the first spraying with lime-sulphur, which was omitted, the Coughlin and Barnes orchards received the regular treatment. With the exception of the first application of both Bordeaux and lime-sulphur, the Coleman, Fergus, Tredway and Buckmaster orchards and the Jonathan block in the Snyder & Roediger orchard were treated according to schedule. The Ingram block in the Snyder & Roediger orchard received the four scheduled applications.

For determining the effect of spray, as shown in the increased yield of marketable fruit, as many trees as the size of our force would permit were selected in each different treatment in each orchard, the apples picked, and commercial results determined. The marketable fruit picked in the Snyder & Roediger, the Fergus, the Tredway, and the Buckmaster orchards was graded in 1's, 2's, and salable culls. For obtaining a reliable estimate of the effect of spraying upon the injurious insects and diseases, six trees in each treatment in each orchard were selected and a careful record kept of all the apples which set. In all cases the trees selected were as nearly typical as possible, and the results obtained are a close approximation of what occurred in the orchards generally.

Summary of Commercial Results. Orchard of John Coughlin, Argentine, Kansas, 1910.

Yield of 15 trees, 5 per plat. Variety, Gano.

PLAT.	No. bushels merchantable fruit.	Per cent merchantable.	No. bushels of cull fruit.	Per cent culls.
Bordeaux	7.85	54.32	6.60	45.68
Lime-sulphur	8.30	60.36	5.45	39.64
Check	0.60	7.14	7.80	92.86

Yield of 15 trees, 5 per plat. Variety, Shackleford.

Bordeaux	22.14	74.27	7.67	25.73
Lime-sulphur	15.76	74.03	5.53	25.97
Check	1.59	42.63	2.14	57.37

Summary of Commercial Results. Orchard of W. E. Barnes, Vinland, Kansas, 1910.

Yield of 30 trees, 10 per plat. Variety, Missouri Pippin.

Bordeaux	30.50	86.65	4.70	13.35
Lime-sulphur	29.25	85.15	5.10	14.85
Check	5.15	49.76	5.20	50.24

Summary of Commercial Results. Orchard of R. W. Coleman, Olathe, Kansas, 1910.

Yield of 15 trees, 5 per plat. Variety, Jonathan.

Bordeaux	2.24	28.21	5.70	71.79
Lime-sulphur	7.37	55.97	5.80	44.03
Check	0.64	12.57	4.45	87.43

Summary of Commercial Results, Orchard of Snyder & Roediger, Parker, Kansas, 1910.

Yield of 30 trees, 10 per plat. Variety, Jonathan.

Bordeaux	71.30	92.80	5.50	7.20
Lime-sulphur	78.70	92.40	6.40	7.60
Check	37.30	89.00	4.60	11.00

Summary of Commercial Results, Orchard of Snyder & Roediger, Parker, Kansas, 1910.

Yield of 20 trees, 10 per plat. Variety, Ingram.

PLAT.	No. bushels merchantable fruit.	Per cent merchantable.	No. bushels of cull fruit.	Per cent culls.
Bordeaux	46.40	91.80	3.90	8.20
Check	25.60	60.60	3 99	39.40

Yield of 9 trees, 3 per plat. Variety, Missouri Pippin.

Lime-sulphur	25.44	72.80	9.48	27.20
Bordeaux	27.48	83.50	5.43	16.50
Check	15.66	65.00	8.40	35.00

Summary of Commercial Results, Orchard of Isham Buckmaster, Ft. Scott, Kansas, 1910.

Yield of 12 trees, 4 per plat. Varieties: Ben Davis, Winesaps.

Bordeaux	33.80	96.80	1.08	3.20
Lime-sulphur	34.20	96.30	1.36	3.70
Check	15 84	81.90	3 48	18.10

Yield of 6 trees, 2 per plat. Variety, Missouri Pippin.

Bordeaux	9.00	73.60	3.24	26.40
Lime-sulphur	3.48	77.67	1.00	22.33
Check[1]	....	....	....	....

[1] Dropped off on account of blotch.

Summary of Commercial Results, Orchard of J. B. Fergus, Mildred, Kansas, 1910.

Yield of 18 trees, 6 per plat. Varieties treated: Ben Davis, York Imperial, Dominie, Maiden Blush. Varieties check: Ben Davis, Jonathan, Missouri Pippin.

Bordeaux	74.60	95.90	3.50	4.10
Lime-sulphur	90.00	87.30	12.00	12.70
Check	.35	5.00	6.80	95 00

Summary of Commercial Results, Orchard of J. T. Tredway, La Harpe, Kansas, 1910.

Yield of 12 trees, 6 per plat. Varieties treated: Ben Davis, York Imperial, Winesaps, Missouri Pippin. Varieties check: Winesap, Ralls Genet, Missouri Pippin, Red Winter Sweet.

Bordeaux	44.34	88 20	5 91	11.80
Check	16.98	65 80	8 82	34 20

In order that the reader may more easily and quickly grasp the meaning of these tables, the following summary has been prepared:

Summary of gains in commercial fruit yield through careful spraying.

VARIETY.	Increase in actual yield in bushels per tree.		Increase in percentage of merchantable fruit.	
	Bordeaux	Lime-sulphur	Bordeaux	Lime-sulphur
Gano	1.45	1.54	47.2	53.2
Shackleford	4.11	2.83	31.6	31.4
Jonathan	.32	1.35	15.6	43.4
Jonathan	3.40	4.14	3.8	3.4
Ingram	2.08		31.2	
Missouri Pippin	2.54	2.41	36.9	35.4
Missouri Pippin	3.94	3.26	18.5	7.8
Missouri Pippin	4.50	1.74	73.6	77.7
Mixed—Ben Davis, Winesap	4.49	4.59	14.9	14.4
Mixed—Ben Davis, York Imperial, Dominie, Maiden Blush, Jonathan, Missouri Pippin	12.37	14.94	90.9	82.3
Mixed—Ben Davis, Winesap, Missouri Pippin, York Imperial, Ralls Genet, Red Winter Sweet	4.56		22.4	
Totals	43.76	36.80	386.6	349.0
Average	3.98	4.09	35.1	38.8

The preceding tables and summary show conclusively that careful spraying increases markedly both the actual and the relative amount of merchantable fruit. The increase in the actual amount of merchantable fruit ranged from .32 to 14.9 bushels per tree, with an average of 4 bushels. The increase in relative amounts of merchantable fruit ranged from 3.4 per cent to 94.3 per cent, with an average of 37 per cent of the total yield. This would mean, granting that the average net selling price of "orchard run" of the standard varieties is about 50 cents per bushel, that careful spraying brought an average gross profit of $2 per tree. The following table shows that the average cost of treatment per tree varied from 5 to 15 cents, with an average of 9.5 cents. The cost is much larger than would be necessary where the grower is prepared for spraying—has good machinery, has it in good order, and has his water close at hand. The cost of labor is the large item in the bill of spraying, and if the arrangements are so nearly perfect that the men will lose the smallest possible amount of time, the spraying will be done for the lowest cost. Granting, however, that spraying costs an average of 9.5 cents per tree and that four treatments are made, there would remain a net profit of $1.62 per tree. Counting sixty trees to the acre, this would mean a net return from careful spraying of $97.20 per acre.

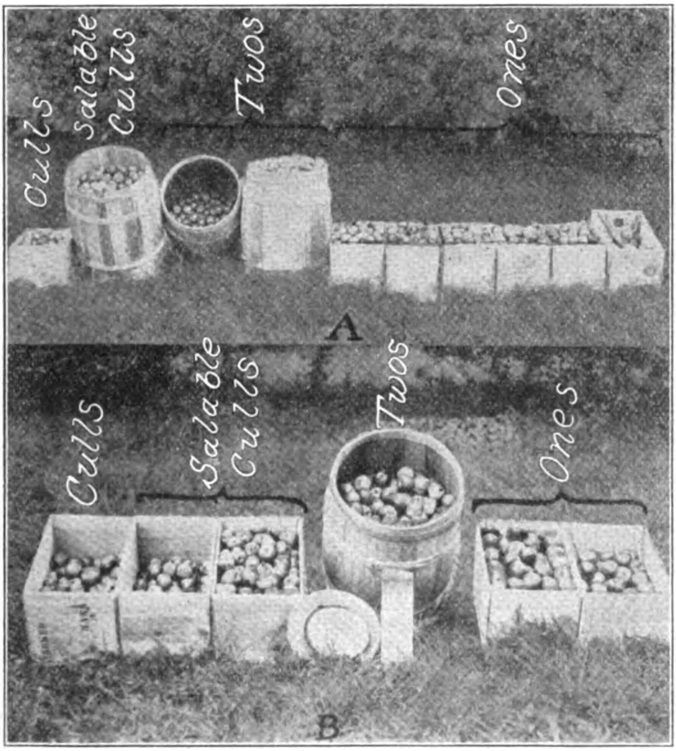

FIG. 2.—An unusually strong result. A. Yield of one sprayed tree. B. Yield of six unsprayed trees.

Table to show actual average cost per tree of spraying in demonstration orchards. This table is based upon data taken in the Snyder & Roediger and the Fergus orchards. It seemed unnecessary to take other orchards into consideration, as the former was a good commercial orchard and the latter an excellent home orchard. For barrel or power sprayer three men and one team were used. The men were paid $2 for a day and the team cost $1.50.

Bordeaux and Arsenate of Lead.

No. of treatment.	VARIETY.	Orchard.	Date of treatment.	No. trees treated...	Length of time in days.......	Type of sprayer used.	Type of material used.	Distance from water.	No. gals. per tree...	Av. cost per tree.		
										For material.	For labor.	Total.
1..........	Ingram...	Snyder & Roediger.	3-31-10	66	.560	Geared power.....	Bordeaux (3-4-50) plus 2 lbs. arsenate of lead.	.5 mile......	3.8	$0.0300	$0.0630	$0.0930
1..........	Mixed....	Fergus.............	3-28-10	74	.670	"Eclipse" No. 6....	Bordeaux (3-4-50) plus 2 lbs. arsenate of lead.	At orchard	3.4	.0265	.0675	.0940
Average cost per tree of 1st. treatment..................										.0280	.0650	.0930
2..........	Ingram...	Snyder & Roediger.	4-19-10	88	.860	"Eclipse" No. 6....	Bordeaux (3-4-50) plus 2 lbs. arsenate of lead.	.5 mile......	4.0	.0300	.0730	.1030
2..........	Jonathan.	Snyder & Roediger.	4-13-10	75	1.130	"Eclipse" No. 6....	Bordeaux (3-4-50) plus 2 lbs. arsenate of lead.	.5 mile......	5.3	.0410	.1130	.1540
2..........	Mixed....	Fergus.............	4-12-10	138	1.300	"Eclipse" No. 6....	Bordeaux (3-4-50) plus 2 lbs. arsenate of lead.	At orchard	4.6	.0350	.0710	.1060
Average cost per tree of 2nd treatment..................										.0353	.0857	.1210
3..........	Ingram...	Snyder & Roediger.	5-18-10	88	.780	"Eclipse" No. 6....	Bordeaux (3-4-50) plus 2 lbs. arsenate of lead.	.5 mile......	4.1	.0310	.0670	.0980
3..........	Jonathan.	Snyder & Roediger.	5-4-10	75	.450	Gasoline power sprayer..........	Bordeaux (3-4-50) plus 2 lbs. arsenate of lead.	.5 mile......	6.1	.0470	.0450	.0920
3..........	Mixed....	Fergus.............	5-11-10	165	1.750	"Eclipse" No. 6....	Bordeaux (3-4-50) plus 2 lbs. arsenate of lead.	At orchard.	6.8	.0530	.0790	.1320
Average cost per tree of 3rd treatment..................										.0437	.0636	.1073
Average cost per tree for Bordeaux treatment..................										.1070	.2143	.3213

No. of treatment.	VARIETY.	Orchard.	Date of treatment.	No. trees treated....	Length of time in days.......	Type of sprayer used.	Type of material used.	Distance from water.	No. gals. per tree...	Av. cost per tree.		
										For material.	For labor.	Total.
Arsenate of Lead Alone.												
4..........	Jonathan.	Snyder & Roediger.	6-20-10	101	.500	Gasoline power sprayer..........	Arsenate of lead 2 lbs. to 50 gal. water.	.5 mile.....	4.7	.0180	.0370	.0550
4..........	Ingram...	Snyder & Roediger.	6-21-10	88	.389	Gasoline power sprayer..........	Arsenate of lead 2 lbs. to 50 gal water.	.5 mile.....	4.5	.0170	.0330	.0500
4..........	Mixed....	Fergus............	6-23-10	187	.667	Gasoline power sprayer..........	Arsenate of lead 2 lbs. to 50 gal. water.	At orchard	5.9	.0220	.0270	.0490
Average cost per tree of 4th treatment..........										.0190	.0320	.0510
Average cost per tree for Bordeaux treatment, including 4th treatment..........										.1260	.2463	.3723
Lime-sulphur and Arsenate of Lead.												
1..........	Mixed....	Fergus............	3-29-10	16	.111	"Eclipse" No. 6....	1.5 gals lime-sulphur to 50 gals. water plus 2 lbs. arsenate of lead.	At orchard.	3.1	.0318	.0518	.0836
2..........	Mixed....	Fergus............	4-12-10	21	.200	"Eclipse" No. 6....	1.5 gals. lime-sulphur to 50 gals. water plus 2 lbs. arsenate of lead.	At orchard.	4.8	.0710	.0480	.1190
2..........	Jonathan.	Snyder & Roediger.	4-14-10	26	.375	"Eclipse" No. 6....	1.5 gals. lime-sulphur to 50 gals. water plus 2 lbs. arsenate of lead.	.5 mile......	5.1	.0480	.1080	.1560
Average cost per tree of 2nd treatment..........										.0600	.0780	.1380
3..........	Jonathan.	Snyder & Roediger.	5-4-10	26	.150	Gasoline power sprayer..........	1.5 gals. lime-sulphur to 50 gals. water plus 2 lbs. arsenate of lead.	.5 mile.....	6.9	.0700	.0430	.1130
3..........	Mixed....	Fergus............	5-11-10	22	.250	"Eclipse" No. 6....	1.5 gals. lime-sulphur to 50 gals. water plus 2 lbs. arsenate of lead.	At orchard.	5.7	.0580	.0850	.1430
Average cost per tree of 3rd treatment..........										.0640	.0640	.1280
Average cost per tree for lime-sulphur treatment..........										.1558	.1938	.3496
Average cost per tree for 4th treatment with arsenate of lead alone..........										.0190	.0320	.0510
Average cost per tree for lime-sulphur treatment, including 4th treatment..........										.1748	.2258	.4006

Summary for preceding table.

Bordeaux.

No. of Treatment.	Av. No. gallons used.	Average cost per tree.		
		For material.	For labor.	Total.
1	3.60	$0.0280	$0.0650	$0.0930
2	4.63	.0353	.0857	.1210
3	5.67	.0437	.0636	.1073
Total	13.90	.1070	.2143	.3213
4	5.03	.0190	.0320	.0510
Grand Total	18.93	.1260	.2463	.3700

Lime-sulphur.

No. of Treatment.	Av. No. gallons used.	For material.	For labor.	Total.
1	3.10	$0.0318	$0.0518	$0.0836
2	4.95	.0600	.0780	.1380
3	6.30	.0640	.0640	.1280
Total	14.35	.1558	.1938	.3496
4	5.03	.0190	.0320	.0510
Grand Total	19.38	.1748	.2258	.4000

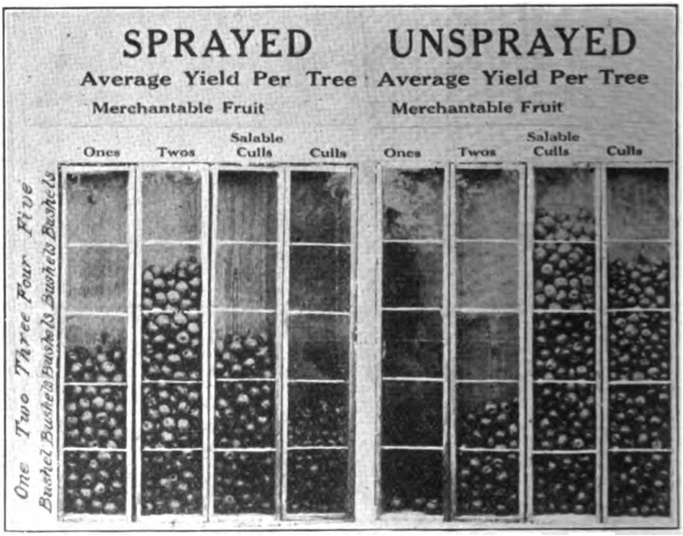

FIG. 3.—Results of spraying Ingrams. Average yield per tree of sprayed as compared with unsprayed, graded into ones, twos, salable culls, and culls. Note the great increase in the ones and twos.

These results come when apples are sold as "orchard run," but the best returns from careful spraying of the apple orchard appear only when the apples are graded, for the reason that the benefit lies largely in the production of larger amounts of the high-priced grades.

Commercial results in graded fruit are available only from the Snyder & Roediger, Fergus, Tredway, and Buckmaster orchards, and our discussion of this phase of the question must therefore be based upon the data gathered in those orchards.

Percentage of 1's, 2's and salable culls in merchantable fruit obtained from sprayed and unsprayed trees in Snyder & Roediger, Fergus, Tredway, and Buckmaster orchards in 1910.

VARIETY.	Orchard	Treatment...	No. of trees taken into considera-tion.........	Per cent of No. 1's......	Per cent of No. 2's......	Per cent of salable culls.
Jonathan................	Snyder & Roediger...	Bordeaux	63	18.7	62.7	18.6
Jonathan................	Snyder & Roediger...	Lime-sulphur.	12	45.5	38.6	15.9
Jonathan................	Snyder & Roediger...	Untreated ...	11	24.2	43.7	32.1
Ingram...................	Snyder & Roediger...	Bordeaux	65	31.4	43.2	25.4
Ingram...................	Snyder & Roediger...	Untreated ...	11	.5	25.8	74.2
Missouri Pippin...	Snyder & Roediger...	Lime-sulphur.	3	11.7	48.1	40.2
Missouri Pippin.........	Snyder & Roediger...	Bordeaux	3	19.2	33.6	47.2
Missouri Pippin.........	Snyder & Roediger...	Untreated ...	3	14.2	42.4	43.4
Mixed	Fergus	Bordeaux	6	35.6	53.2	11.2
Mixed	Fergus	Lime-sulphur.	5	33.2	58.4	8.4
Mixed	Fergus	Untreated ...	6	....	....	100.0
Mixed	Tredway	Bordeaux	6	30.2	59.7	10.1
Mixed	Tredway	Untreated ...	6	24.6	37.7	37.7
Mixed	Buckmaster..........	Bordeaux	6	33.2	56.0	10.6
Mixed	Buckmaster..........	Lime-sulphur.	6	42.5	51.8	5.7
Mixed	Buckmaster..........	Untreated ...	6	14.9	67.8	17.3
Average	....	Bordeaux	....	27.9	51.0	21.1
Average	....	Lime-sulphur.	....	32.9	49.6	17.5
Average	....	Untreated ...	....	15.8	43.8	40.4

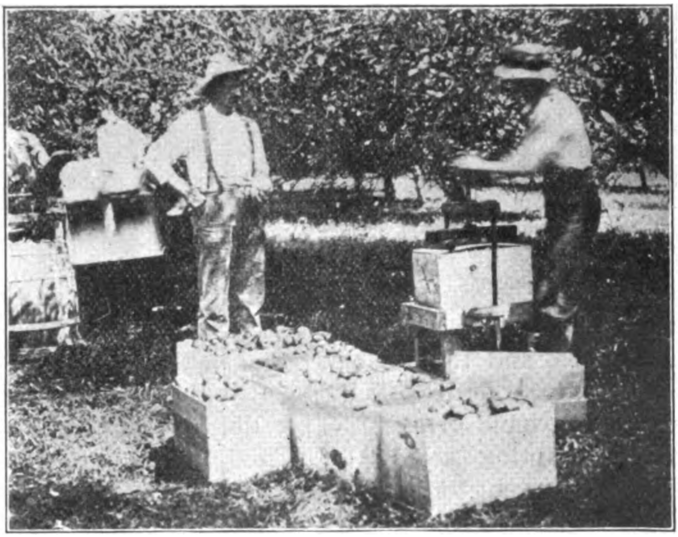

FIG. 4.—Boxing the ones.

This table shows clearly that when the merchantable apples are properly graded the average of the sprayed trees shows 12.1 to 17.1 per cent more of number 1's, 5.8 to 7.2 per cent more of number 2's, and 19.3 to 22.9 per cent less of salable culls. For the sake of illustration, let us take an average lime-sulphur-sprayed Jonathan apple tree which bears 7.87 bushels of merchantable fruit. Forty-five and five-tenths per cent, or 3.58 bushels, are number 1's, 38.6 per cent, or 3.04 bushels, are number 2's, and 15.9 per cent, or 1.25 bushels, are salable culls. Sold as "orchard run," without grading, the 7.87 bushels would bring about $3.94, while if sold as grades, might well bring number 1's $1.50 per bushel, number 2's $0.80 per bushel, and salable culls $0.20 per bushel, amounting to $8.05, a difference of $4.11. Or, let us take 100 bushels of marketable Jonathans from trees treated with lime-sulphur. Forty-five and five-tenths bushels are number 1's, 38.6 bushels are number 2's, and 15.9 bushels are salable culls. If sold as "orchard run," the entire 100 bushels would bring $50. If sold as grades, they would bring $1.50 for 1's, $0.80 for 2's, and $0.20 for culls, amounting to $102.31. This means an increase of more than 50 per cent to pay for the trouble of grading.

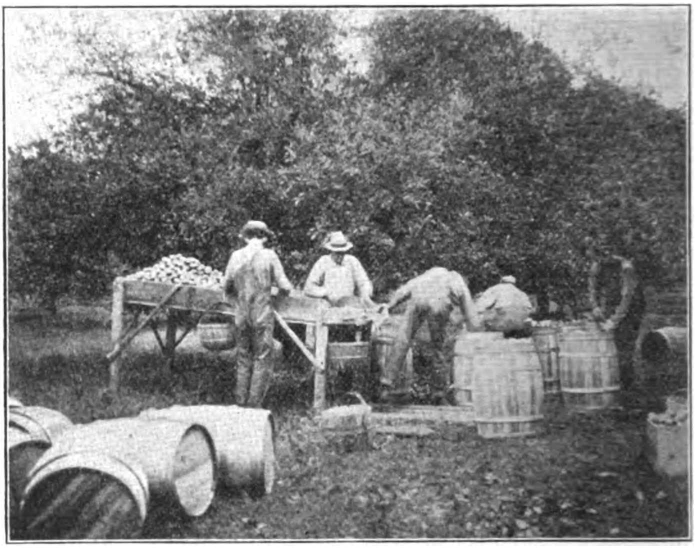

FIG. 5.—Barreling the twos.

The results obtained this year can be duplicated or bettered by any one who will take the necessary amount of trouble to familiarize himself thoroughly with the methods used. There is no reason why the farmer should not have plenty of apples of good quality for his family. There is no reason in the presence of injurious insects and fungi to prevent commercial orchardists from establishing themselves in large numbers in Kansas. There is much good orchard land to be had at comparatively low cost.

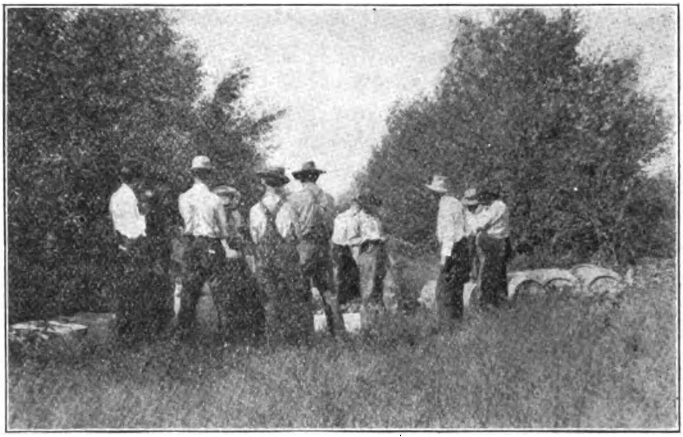

FIG. 6.—The neighbors examined the results of demonstration spraying at picking time.

How These Results Were Obtained.

Protecting the Apple from Insect and Fungous Enemies.

PRINCIPAL INSECT ENEMIES.

The codling-moth and the plum curculio are the only insects that we need to consider, because such leaf feeders as the apple-leaf crumpler, apple tree tent caterpillar, canker-worms, and fall web-worm are controlled incidentally by the sprays intended for the former. Close observations upon the codling-moth and curculio were limited to the Snyder & Roediger orchard at Parker, Kansas.

By the time we were ready to begin work, April 16, which was almost four weeks after the Jonathan trees were in full bloom, the earliest of the moths were already on the wing. From this date until June 18 frequent collections of larvæ and pupæ were made from the trunks of the trees. In all, ninety-eight larvæ and pupæ were taken, and of these, forty produced healthy moths, the majority of which had emerged by June 5. For eight of the forty the length of pupal stage was determined. It ranged from fourteen to seventy-four days, with an average of thirty-six days.

The work of the larvæ produced by this first brood of moths was noticed when the first dropped apples were examined early in July. Shortly before July 11 these larvæ began to leave the apples in considerable numbers. The emergence of this brood of "worms" reached its height shortly after the middle of July. Most of these larvæ promptly transformed to pupæ. Careful observation of fifty-six cases shows that the pupal stage occupied an average of nine days. The emergence of the second brood of moths reached its height about the first of August. The larvæ produced by this brood reached their height of emergence from the apples about the middle of September. In the latter part of August our records show a considerable increase in the number of moths emerging. Very few of the larvæ which emerged from the apples after the middle of August transformed to pupæ.

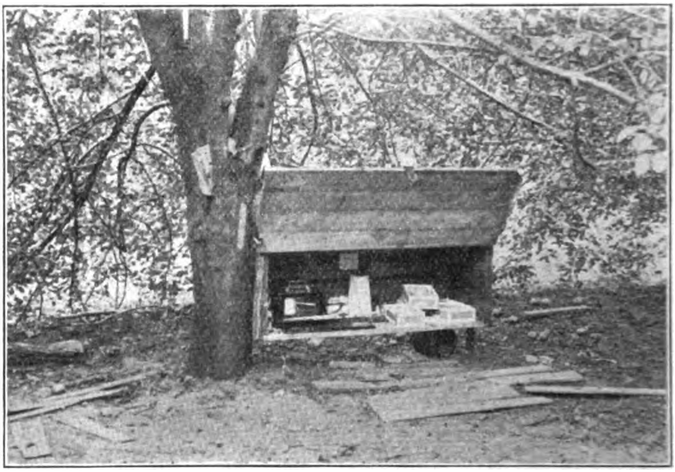

FIG. 7.—Where the development of the codling-moth was followed.

Curculio injury appeared in the apple at the first examination of the dropped fruit early in July, and this early drop was largely wormy with curculio grubs. Late in the season some harm was done to the apple by feeding of the second brood of beetles. It is evident, however, that a satisfactory remedy for this insect must be directed at the first brood, and must be applied during the early part of the season, while the apples are yet small.

PRINCIPAL FUNGOUS ENEMIES.

Apple scab, sooty blotch, apple blotch, black rot, and bitter rot were serious enough to require attention. Apple scab appeared on the unsprayed Ingrams and did much harm, but was rarely noted on the other varieties. Likewise, the work of sooty blotch damaged the Ingrams mainly. Apple blotch was mainly confined to Missouri Pippins, although it appeared on the fruit of other varieties. Black rot made its appearance on all varieties, but did little harm.

Bitter rot attacked a few of the Jonathan trees and destroyed most of the fruit on the infected trees. It struck only a few trees and they were well separated from each other.

METHODS USED.

The method used for the destruction of these insects and fungi is the outcome of a vast amount of experience accumulated by workers in this line in all parts of the United States. When we take into consideration the fact that this treatment must destroy both plant and animal parasites, yet leave the host or tree unharmed, it is not difficult to understand that the problem is sufficiently complex to render the accumulation of a large number of facts necessary before an efficient method could be developed. The procedure for this purpose has three very important phases—the nature of the material which should be used, the time when it should be applied, and the manner of its application.

MATERIAL.

The material is composed of two active substances, one of which is intended to destroy the insects and the other to control fungi. The first is arsenic, put up in the form of arsenate of lead. This is a stomach poison which must be placed on the substances which the insects will later consume. This form of arsenic has been adopted because it has so small an amount of free arsenious acid that it does not burn foliage or fruit, and because it clings to the foliage and fruit exceedingly well and consequently resists the washing of the rains.

The second substance is copper sulphate, sometimes known as blue stone, or blue vitriol. It is used in combination with milk of lime to form Bordeaux mixture, the active principle of which consists of copper hydroxide. The copper hydroxide spreads well over foliage and fruit and adheres closely thereto. It resists the washing of the rains well. It is thought that small amounts of this copper are brought into solution and thus in contact with the spores of fungous diseases, destroying them. That property of Bordeaux mixture which causes it under certain favorable conditions seriously to injure susceptible varieties has led to the trial of substitute substances. The most promising of these is the prepared or concentrated lime-sulphur solutions. Although we know little or nothing about exactly how the lime-sulphur kills the disease spores, the fact of its ability to control most of the apple diseases has been firmly established.

These substances were applied in two combinations—two pounds of lead arsenate mixed thoroughly with fifty gallons of 3-4-50 Bordeaux, and two pounds of lead arsenate and one and one-half gallons of prepared lime-sulphur solution, testing 33° Baume thoroughly mixed with fifty gallons of water. The method of mixing the lead arsenate was the same in each combination. The required amount was weighed out in a bucket and mixed with a little water until it would flow readily; it was then poured into the tank of Bordeaux or the diluted lime-sulphur and thoroughly stirred by setting the agitator in vigorous motion. The Bordeaux was made up in the usual manner. Stock solutions of copper sulphate and lime were made in barrels each containing one pound of the substance to one gallon of water. Two dilution tanks made of barrels were employed. In making up fifty gallons, three gallons of stock solution of copper sulphate were placed in the copper sulphate dilution tank. Four gallons of the milk of lime were placed in the lime dilution tank. Sufficient water was added to each tank to make twenty-five gallons in each. The plugs were then removed from the drain pipes and the dilute copper sulphate and milk of lime were allowed to run together through the burlap strainer into the spray tank. The lead was then added. In preparing fifty gallons of the lime-sulphur, about fifty gallons of water were placed in the spray tank. One and one-half gallons of the prepared lime-sulphur mixture were measured out and mixed thoroughly with the water. The lead arsenate was added as before.

It is important to obtain for the stock lime solution a type of unslacked lime that will leave no lumps or coarse particles after slacking. The Sherwin-Williams' and Grasseli Chemical Company's prepared lime-sulphur solutions were used, and both were satisfactory. Swift's Arsenate of Lead and Grasseli Chemical Company's product were employed with equally satisfactory results.

TIME.

The time when the applications should be made is determined by knowledge, based upon the life history of the insects and fungi in question, of when such treatments are likely to be most effective.

From the time the bud opens until the apple approaches picking time it is open to the attack of fungous diseases—first scab, then blotch, sooty blotch and fly speck, black rot and, later, bitter rot. For a similar period the foliage and, to a less extent, the fruit are open to the attacks of various foliage-consuming larvæ. From a few weeks after the apples set until almost picking time, they are constantly attacked by codling-moth larvæ. From setting of the apples for a period of about one and one-half months they are subject to curculio "stinging," and late in the season they are fed upon by the new brood of curculio. The method most likely to protect the apple would seem to be to keep the foliage and fruit covered with spray throughout the season, and this could be best accomplished by spraying at regular and short intervals. Other considerations modify this schedule, however. The fact that eighty per cent of the first brood of codling-moth larvæ, and a large percentage of the second, enter the blossom end of the apple, connected with the fact that for several days after the petals drop this blossom end is wide open and easily filled with poison, which will soon be enclosed and held ready for all "worms" that enter, renders treatment at this time of greatest importance. Likewise, the concentration of serious curculio attack during a short period beginning with the setting of the apples, and attempts of apple scab and apple blotch to establish themselves in the tender tissue, render early treatment very important.

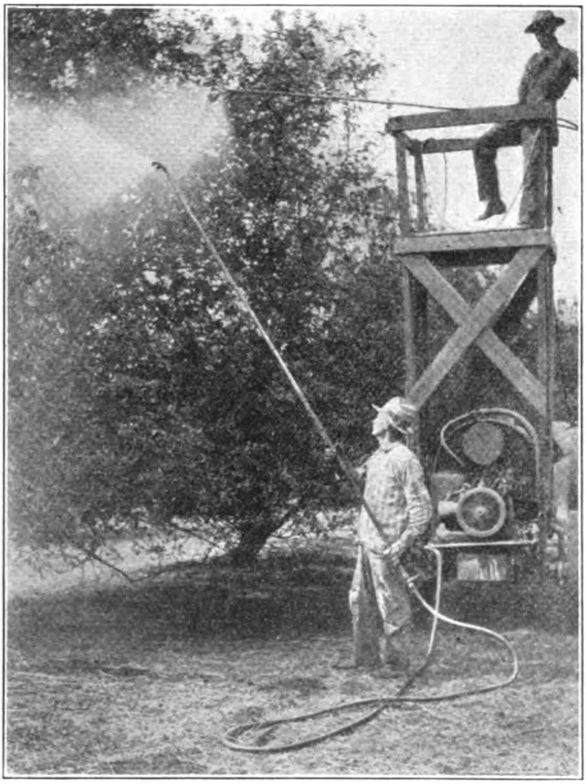

FIG. 8.—The gas engine at work (Photo by C. V. Holsinger.)

APPLICATION.

The mixtures were applied by means of barrel, geared, and gas-engine sprayers. The pressure ranged from 80-120 pounds in the barrel pump, through 100-160 pounds in the geared sprayer, to 140-225 pounds in the gas-engine outfit. All Bordeaux and lime-sulphur sprays were delivered as a fine mist, which gave the trees a good, even coat. Spraying was continued until all parts of each tree were thoroughly covered. In the second application the spray was shot down into the open blossom ends. From four to eight gallons per tree were used.

SCHEDULE OF APPLICATION.

First Application.—As the cluster buds open but before blossoming, spray thoroughly with Bordeaux mixture and lead arsenate or with prepared lime-sulphur and lead arsenate.

Second Application.—As soon as the majority of the petals have fallen spray thoroughly with Bordeaux mixture and lead arsenate or with prepared lime-sulphur and lead arsenate.

Third Application.—Three weeks after the falling of the petals spray thoroughly with Bordeaux mixture and lead arsenate or with prepared lime-sulphur and lead arsenate.

Fourth Application.—Ten weeks after the falling of the petals spray thoroughly with arsenate of lead alone, using two pounds to fifty gallons of water.

RESULTS.

In determining the efficiency of the spraying mixtures for the control of insects and fungous diseases more than a quarter of a million apples were individually examined. To be exact, 256,240 apples in the seven orchards were taken into consideration. Large numbers have been used in the hope that the effect of local conditions might be eliminated and the results be made representative. For each block under treatment three summaries are presented, the first dealing with the dropped fruit, the second with the picked fruit, and the third with the total of both dropped and picked. Owing to the fact that insect and fungous attacks operate for a time, then cease to be active, coupled with the fact that dropping of infested fruit is correlated with the physiological condition of the tree, which is immediately dependent upon surrounding conditions, the consideration of the whole amount of fruit which set was the only means by which we could reach a true conception of what the sprays accomplished.

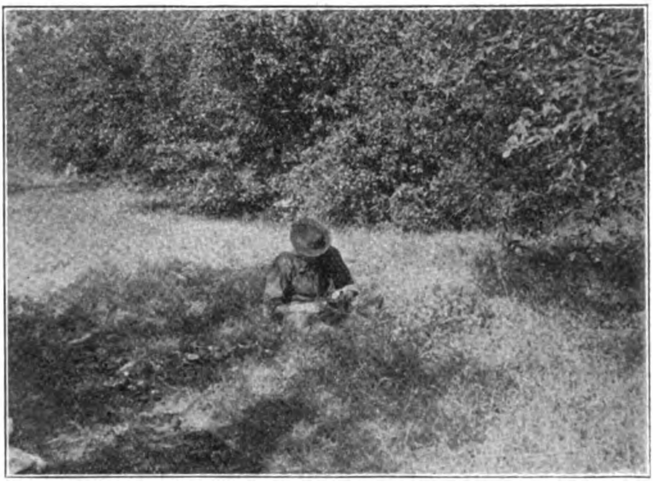

Fig. 9.—"In determining the efficiency of the spraying mixtures . . . more than a quarter of a million apples were individually examined." Examining the fallen fruit.

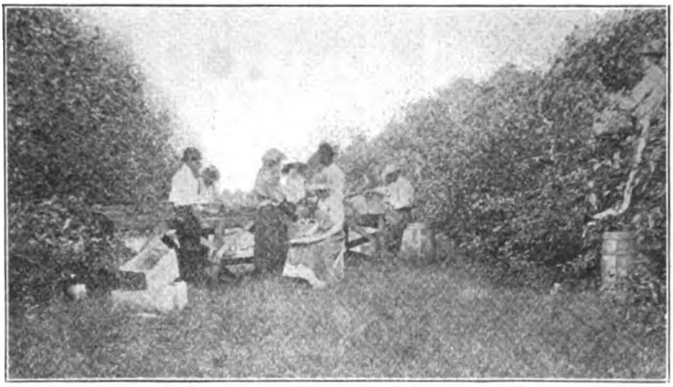

Fig. 10.—"In determining the efficiency of the spraying mixtures . . . more than a quarter of a million apples were individually examined." Examining the picked apples.

Spraying Results, Orchard of John Coughlin, Argentine, Kansas, 1910.

Bordeaux Plat, Trees 2, 5, 6, 9, 10. Variety, Gano.

	Total No......	Codling-moth....	Per cent....	Curculio	Per cent....	Scab......	Per cent....	Apple blotch..	Per cent....	Sooty blotch..	Per cent....	Bitter rot......	Per cent....	Black rot......	Per cent....	Spray injury..	Per cent....	Sound fruit....	Per cent....
Windfalls....................	1018	103	10.10	755	74.1	83	8.10	1	.09	.....	.....	.....	.....	....	.....	.....	.....	89	8.80
Picked fruit	2447	156	6.30	2318	94.1	164	6.60	20	.80	....	.....	.....	.....	.....	.....	.....	.....	18	.70
Grand total..............	3165	259	7.40	3073	85.8	247	7.10	21	.60	.....	.....	.....	.....	.....	.....	.....	.....	107	3.08

Lime-sulphur Plat, Trees 2, 5, 6, 9, 10. Variety, Gano.

	Total No......	Codling-moth....	Per cent....	Curculio	Per cent....	Scab......	Per cent....	Apple blotch..	Per cent....	Sooty blotch..	Per cent....	Bitter rot......	Per cent....	Black rot......	Per cent....	Spray injury..	Per cent....	Sound fruit....	Per cent....
Windfalls........	708	78	11.01	632	89.2	50	7.06	.....	...	.....	....	.....	.....	.....	.....	.....	.....	27	3.80
Picked fruit	2590	228	8.60	2501	96.5	229	8.64	162	6.20	.....	.....	....	.....	.....	...	....	.....	....	.....
Grand total............ .	3298	306	9.20	3133	94.9	279	8.40	162	4.90	.....	.....	.....	.....	....	.....	.....		27	.80

Check Plat. Trees 3, 5, 6, 9. Variety, Gano.

	Total No......	Codling-moth....	Per cent....	Curculio	Per cent....	Scab......	Per cent....	Apple blotch..	Per cent....	Sooty blotch..	Per cent....	Bitter rot......	Per cent....	Black rot......	Per cent....	Spray injury..	Per cent....	Sound fruit....	Per cent....
Windfalls..	1259	602	47.80	1251	99.3	541	42.90	71	5.60	.....	.....	.....	....	.....	...	.....	.....	.....	.....
Picked fruit...	1284	733	57.00	1283	99.9	850	66.20	143	11.10	.....	....	.....	...	.....	.....	.....	....	.....	.....
Grand total.......	2543	1335	52.40	2534	99.6	1391	51.60	214	8.40	....	.....	.....		.....	.....	.....	....	.....	.....

Bordeaux Plat. Trees 1, 3, 4, 7, 8. Variety, Shackleford.

	Total No......	Codling-moth....	Per cent....	Curculio	Per cent....	Scab......	Per cent....	Apple blotch..	Per cent....	Sooty blotch..	Per cent....	Bitter rot......	Per cent....	Black rot......	Per cent....	Spray injury..	Per cent....	Sound fruit....	Per cent....
Windfalls.....................	1957	113	5.70	1723	88.0	74	2.70	15	.76	.....	.....	.....	.....	.....	.....	....	.....	152	7.70
Picked fruit	3927	60	1.50	3675	93.5	127	3.20	43	1.09	.....	.....	.....	.....	.....	.....	.....	.....	85	2.16
Grand total........... ...	5884	173	2.90	5398	91.7	201	3.40	58	.98	.....	.....	.....	.....	.....	.....	.....	.....	237	4.02

Lime-sulphur Plat, Trees 1, 2, 4, 7, 8. Variety, Shackleford.

	Total No......	Codling-moth....	Per cent....	Curculio	Per cent....	Scab......	Per cent....	Apple blotch..	Per cent....	Sooty blotch..	Per cent....	Bitter rot......	Per cent....	Black rot......	Per cent....	Spray injury..	Per cent....	Sound fruit....	Per cent....
Windfalls....................	1332	61	4.50	1244	93.8	129	9.60	115	8.60	.....	.....	.....	.....	.....	.....	.....	.....	20	1.50
Picked fruit..................	2804	74	2.60	2236	79.7	208	7.40	162	5.60	.....	.....	.....	.....	.....	.....	.....	.....	269	9.50
Grand total..............	4126	135	3.20	3480	81.8	337	7.40	277	5.60	.....	.....	.....	.....	.....	.....	.....	.....	289	6.90

	Total No.	Codling-moth	Per cent	Curculio	Per cent	Scab	Per cent	Apple blotch	Per cent	Sooty blotch	Per cent	Bitter rot	Per cent	Black rot	Per cent	Spray injury	Per cent	Sound fruit	Per cent
Check Plat, Trees 1, 2, 4, 7, 8. Variety, Shackleford.																			
Windfalls	1653	705	42.60	1630	98.60	714	13.20	377	22.8	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Picked fruit	487	150	30.80	475	97.30	268	55.00	61	12.5	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Grand total	2140	855	39.90	2105	98.30	982	45.40	438	20.1	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Spraying Results, Orchard of W. E. Barnes, Vinland, Kansas, 1910.																			
Bordeaux Plat, Trees 13-17, 19, 21, 30, 31, 32. Variety, Missouri Pippin.																			
Windfalls	2245	176	7.80	358	15.90	.....	.....	295	13.1	.....	.....	.....	.....	.....	.....	.....	.....	1426	63.50
Picked fruit	9841	125	1.20	1512	15.30	5	.05	981	9.9	.....	.....	.....	.....	.....	.....	.....	.....	7215	72.40
Grand total	12086	301	2.40	1870	15.30	5	.04	1279	15.8	.....	.....	.....	.....	.....	.....	.....	.....	8641	71.50
Lime-sulphur Plat, Trees 7-12, 26-29. Variety, Missouri Pippin.																			
Windfalls	2013	70	3.47	310	15.40	1	.05	297	14.7	.....	.....	.....	.....	.....	.....	.....	.....	1335	66.30
Picked fruit	9654	49	.50	1439	14.90	7	.07	995	10.3	.....	.....	.....	.....	.....	.....	.....	.....	7164	74.20
Grand total	11667	119	1.01	1749	14.10	8	.08	1292	11.0	.....	.....	.....	.....	.....	.....	.....	.....	8499	72.80
Check Plat, Trees 1-6, 22-25. Variety, Missouri Pippin.																			
Windfalls	9996	3735	37.30	4850	48.50	74	.70	8445	84.4	.....	.....	.....	.....	.....	.....	.....	.....	7	.07
Picked fruit	2810	301	10.70	1428	50.80	10	.35	2219	78.9	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Grand total	12806	4036	31.30	6278	49.00	84	.65	10664	83.2	.....	.....	.....	.....	.....	.....	.....	.....	7	.05
Spraying Results, Orchard of R. W. Coleman, Olathe, Kansas, 1910.																			
Bordeaux Plat, Trees 1-5. Variety, Jonathan.																			
Windfalls	427	75	15.20	300	70.20	1	.20	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	103	24.10
Picked fruit	1283	646	50.30	1155	90.02	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Grand total	1710	721	42.10	1455	85.08	1	.05	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	103	6.02

Lime-sulphur Plat, Trees 1-5. Variety, Jonathan.

	Total No......	Codling-moth...	Per cent....	Curculio.......	Per cent....	Scab.....	Per cent....	Apple blotch..	Per cent....	Sooty blotch..	Per cent....	Bitter rot......	Per cent....	Black rot.....	Per cent....	Spray injury..	Per cent....	Sound fruit....	Per cent....
Windfalls....................	265	18	6.79	223	84.1	6	2.26	1	.37	......	......	......	....	......	......	......	......	21	7.29
Picked fruit.................	2451	270	11.00	2110	86.0	23	.93	37	1 50	......	......	......	......	......	......	......	......	61	2.48
Grand total..............	2716	288	10.60	2333	85.8	29	1.06	38	1.35	......	......	......	......	......	......	......	......	82	3.01
Check Plat. Trees 6-10. Variety, Jonathan.																			
Windfalls....................	747	88	11.70	716	95.8	18	2.40	......	......	......	......	......	......	......	......	......	......	15	2.00
Picked fruit....	871	455	51.80	852	97.8	64	7.30	42	4.80	......	......	......	......	......	......	......	......	......	......
Grand total	1618	543	33.50	1568	96.9	82	5 09	42	2.59	.....	......	......	......	......	......	......	......	15	.90

Spraying Results, Orchard of Snyder & Roediger, Parker, Kansas, 1910.

Bordeaux Plat. Trees 7-12. Variety, Jonathan.

	Total No......	Codling-moth...	Per cent....	Curculio.......	Per cent....	Scab.....	Per cent....	Apple blotch..	Per cent....	Sooty blotch..	Per cent....	Bitter rot......	Per cent....	Black rot.....	Per cent....	Spray injury..	Per cent....	Sound fruit....	Per cent....
Windfalls....................	2158	171	7.80	1174	54.4	3	.130	3	.130	109	5.05	163	7.5	7	.32	775	35.40	620	82.70
Picked fruit.................	15547	79	.50	5413	38.4	....	......	......	......	7	.04	542	3.4	......	......	6923	44.50	9506	61.10
Grand total..............	17705	250	1.40	6587	37.2	3	.016	3	.016	116	.65	705	3.9	7	.03	7698	43.40	10126	57.10
Lime-sulphur Plat, Trees 1-6. Variety, Jonathan.																			
Windfalls....................	3413	157	4.60	1418	41.5	1	.029	4	.11	......	......	91	2.6	7	.2	75	2.19	1738	50.90
Picked fruit.................	16263	68	.42	3789	23.2	....	......	74	.45	752	4.60	233	1.4	......	......	482	2.30	11347	69.70
Grand total..............	19676	225	1.10	5207	26.4	1	.001	78	.39	752	.38	324	1.6	7	.03	557	2.80	13085	66.50
Check Plat. Trees 13-18. Variety, Jonathan.																			
Windfalls....................	3644	865	23.70	2890	79.3	30	.82	14	.38	225	6.10	372	10.2	11	.300	......	......	500	13.70
Picked fruit...........	7519	336	4.40	2814	37.2	....	...	12	.15	1494	19.80	151	2.0	1	.013	......	......	2711	36 00
Grand total..............	11163	1201	10.70	5704	51.0	30	.26	26	.23	1719	15.30	523	4.6	12	.100	......	......	3211	28.70

Bordeaux Plat. Trees 25-30. Variety, Ingram.

	Total No......	Codling-moth....	Per cent....	Cur-culio....	Per cent....	Scab......	Per cent....	Apple blotch..	Per cent....	Sooty blotch..	Per cent....	Bitter rot......	Per cent....	Black rot......	Per cent....	Spray injury...	Per cent....	Sound fruit....	Per cent....
Windfalls.....................	417	34	8.2	165	39.5	40	9.58	......	......	3	.7	27	6.4	......	......	......	......	148	35.4
Picked fruit..................	8050	1736	21.5	2068	25.0	1730	21.49	......	......	1639	20 3	876	10.8	......	......	......	......	4804	59.6
Grand total..............	8467	1770	20.9	2233	26.3	1770	20.90	......	......	1642	19.2	903	10.6	......	......	......	......	4952	58.5

Check Plat, Trees 19-24. Variety, Ingram.

	Total No......	Codling-moth....	Per cent....	Cur-culio....	Per cent....	Scab......	Per cent....	Apple blotch..	Per cent....	Sooty blotch..	Per cent....	Bitter rot......	Per cent....	Black rot......	Per cent....	Spray injury...	Per cent....	Sound fruit....	Per cent....
Windfalls.....................	2125	665	31.2	1750	82 3	1729	81.30	......	......	812	38.3	376	17.6	65	3.05	......	......	80	3.7
Picked fruit..................	10161	2895	18.6	4278	42.1	4628	45.50	......	......	6705	65.9	508	4.9	250	2.40	......	......	586	5.7
Grand total..............	12286	3560	28.9	6028	49.0	6357	51.60	......	......	7517	61.1	884	7.2	315	2.50	......	......	666	5.4

Spraying Results, Orchard of Isham Buckmaster, Fort Scott, Kansas, 1910.

Bordeaux Plat, Trees 2, 12. Variety, Ben Davis.

	Total No......	Codling-moth....	Per cent....	Cur-culio....	Per cent....	Scab......	Per cent....	Apple blotch..	Per cent....	Sooty blotch..	Per cent....	Bitter rot......	Per cent....	Black rot......	Per cent....	Spray injury...	Per cent....	Sound fruit....	Per cent....
Windfalls.....................	387	25	6.5	113	29.2	1	.250	12	3 10	......	......	35	9.0	1	.250	144	37.2	200	51.6
Picked fruit..................	2051	131	6.3	410	20.0	......	......	38	1.36	......	......	78	3.8	......	......	......	......	1596	77.8
Grand total..............	2438	156	6.4	523	21.4	1	.041	50	2.05	......	......	113	4.8	1	.041	144	5.9	1796	73.6

Lime-sulphur Plat, Trees 4, 9 Variety, Ben Davis.

	Total No......	Codling-moth....	Per cent....	Cur-culio....	Per cent....	Scab......	Per cent....	Apple blotch..	Per cent....	Sooty blotch..	Per cent....	Bitter rot......	Per cent....	Black rot......	Per cent....	Spray injury...	Per cent....	Sound fruit....	Per cent....
Windfalls.....................	500	47	9.4	125	25.0	7	1.40	66	13.20	......	......	72	14.4	12	2.40	73	14.6	171	34.2
Picked fruit..................	3175	271	8.5	666	20.9	42	1.30	894	28.10	......	......	268	8.4	......	......	......	......	2100	66.1
Grand total..............	3675	318	8 6	791	21.5	49	1.37	960	26.10	......	......	340	9.2	12	.30	73	1.7	2271	2.6

Check Plat, Trees 13, 16. Variety, Ben Davis.

	Total No......	Codling-moth....	Per cent....	Cur-culio....	Per cent....	Scab......	Per cent....	Apple blotch..	Per cent....	Sooty blotch..	Per cent....	Bitter rot......	Per cent....	Black rot......	Per cent....	Spray injury...	Per cent....	Sound fruit....	Per cent....
Windfalls.....................	911	275	30.1	645	70.8	77	8.46	320	35.10	......	......	215	23.6	87	9.50	......	......	66	7.2
Picked fruit..................	858	245	28.6	422	49.1	40	4.60	514	55.90	......	......	157	18.2	......	.....	......	......	264	30.7
Grand total..............	1769	520	29.3	1067	60.2	117	6.60	834	47.10	......	......	372	21.2	87	4.30	......	......	330	18.6

Bordeaux Plat, Trees 1, 6. Variety, Missouri Pippin.

	Total No.	Codling-moth	Per cent	Curculio	Per cent	Scab	Per cent	Apple Blotch	Per cent	Sooty blotch	Per cent	Bitter rot	Per cent	Black rot	Per cent	Spray injury	Per cent	Sound fruit	Per cent
Windfalls	1317	71	5.30	541	41.0	5	.37	777	58.9	......	......	449	34.09	64	4.80	61	4.30	103	7.8
Picked fruit	4860	349	7.20	1401	28.8	106	2.10	1968	40.4	......	......	633	13 02	......	......	150	3 08	2659	52.6
Grand total	6177	420	6.70	1 942	24.1	111	1.79	2745	44.4	......	......	1082	17.50	64	1.03	211	3.40	2762	44.7

Lime-sulphur Plat, Trees 2, 5. Variety, Missouri Pippin.

	Total No.	Codling-moth	Per cent	Curculio	Per cent	Scab	Per cent	Apple Blotch	Per cent	Sooty blotch	Per cent	Bitter rot	Per cent	Black rot	Per cent	Spray injury	Per cent	Sound fruit	Per cent
Windfalls	5193	23	.45	1124	21.6	7	.13	4581	88 2	......	......	2551	49.10	1354	26.0	27	.50	68	1.1
Picked fruit	1201	151	13.07	508	42.2	......	......	466	38.8	......	......	204	16.90	......	......	......	......	442	36.7
Grand total	6394	174	2.80	1632	25.5	7	.10	5047	78.9	......	......	2758	43.10	1354	21.10	27	.40	510	7.9

Check Plat, Trees 17, 18. Variety, Missouri Pippin.

	Total No.	Codling-moth	Per cent	Curculio	Per cent	Scab	Per cent	Apple Blotch	Per cent	Sooty blotch	Per cent	Bitter rot	Per cent	Black rot	Per cent	Spray injury	Per cent	Sound fruit	Per cent
Windfalls	2819	305	10.80	2266	80.3	1196	42.40	2766	98.1	......	......	960	34.05	1059	37.50	......	......	46	1.6
Picked fruit	65	16	24.60	15	23.0	8	12.30	43	66.1	......	......	10	15.30	......	......	......	......	......	......
Grand total	2884	321	11.10	2281	75.6	1204	41.40	2809	97.3	......	......	970	30.80	1059	36.70	......	......	46	1.5

Bordeaux Plat, Trees 7, 11. Variety, Winesap.

	Total No.	Codling-moth	Per cent	Curculio	Per cent	Scab	Per cent	Apple Blotch	Per cent	Sooty blotch	Per cent	Bitter rot	Per cent	Black rot	Per cent	Spray injury	Per cent	Sound fruit	Per cent
Windfalls	767	47	6.12	251	32.7	11	1.43	......	......	......	......	176	22.90	......	......	274	35.70	282	36.7
Picked fruit	7944	422	5.31	1271	15.9	104	1.30	......	......	......	......	47	5.90	......	......	6908	86.90	6152	81.2
Grand total	8711	469	5.38	1522	17.4	115	1.30	......	......	......	......	223	2.50	......	......	7182	82.30	6734	77.3

Lime-sulphur Plat, Trees 8, 10. Variety, Winesap.

	Total No.	Codling-moth	Per cent	Curculio	Per cent	Scab	Per cent	Apple Blotch	Per cent	Sooty blotch	Per cent	Bitter rot	Per cent	Black rot	Per cent	Spray injury	Per cent	Sound fruit	Per cent
Windfalls	556	45	8.09	128	23.0	10	1.70	21	3.7	......	......	87	15 60	......	......	......	......	265	47.6
Picked fruit	5814	304	5.28	2638	45.3	79	1.30	228	3.9	45	.77	76	1.30	......	......	105	1 80	4386	75.4
Grand total	6370	349	5.47	2766	43.3	89	1 30	249	3.9	45	.70	163	2.50	......	......	105	1.60	4651	73.0

Check Plat, Trees 14, 15. Variety, Winesap.

	Total No.	Codling-moth	Per cent	Curculio	Per cent	Scab	Per cent	Apple blotch	Per cent	Sooty blotch	Per cent	Bitter rot	Per cent	Black rot	Per cent	Spray injury	Per cent	Sound fruit	Per cent
Windfalls	2449	379	10.9	1016	41.00	425	17.30	17	.6	......	......	261	10.6	3	.10	......	......	348	13.80
Picked fruit	3948	966	24.4	1203	30.40	708	17.60	54	1.3	177	4.4	152	3.8	......	......	......	......	1807	45.60
Grand total	6397	1315	21.2	2219	36.20	1133	17.70	71	1.1	177	2.7	413	6.4	3	.04	......	.....	2155	33.60

Spraying Results, Orchard of J. B. Fergus, Mildred, Kansas, 1910.

Bordeaux Plat, Trees 1-4. Varieties: Ben Davis, York Imperial, Dominie.

	Total No.	Codling-moth	Per cent	Curculio	Per cent	Scab	Per cent	Apple blotch	Per cent	Sooty blotch	Per cent	Bitter rot	Per cent	Black rot	Per cent	Spray injury	Per cent	Sound fruit	Per cent
Windfalls	8685	127	1.4	821	9.40	70	.80	113	1.3	......	......	379	4.3	33	3.70	262	3.0	7244	83.20
Picked fruit	11150	496	4.4	1887	16.80	130	1.10	127	1.1	122	1.1	115	1.0	......	.....	1036	9.0	8989	80.60
Grand total	19835	623	3.1	2708	13.60	200	1.00	240	1.2	122	.6	494	2.4	33	.16	1298	6.5	16233	81.80

Lime-sulphur Plat, Trees 7-10. Varieties: Ben Davis, Dominie, York Imperial.

	Total No.	Codling-moth	Per cent	Curculio	Per cent	Scab	Per cent	Apple blotch	Per cent	Sooty blotch	Per cent	Bitter rot	Per cent	Black rot	Per cent	Spray injury	Per cent	Sound fruit	Per cent
Windfalls	4596	412	8.9	910	11.00	85	1.80	505	11.0	15	.3	38	12.2	100	21.70	202	4.2	1908	41.07
Picked fruit	13645	1555	11.3	2687	19.06	116	.80	1567	11.4	2527	18.2	83	4.2	......	......	2104	15.3	9085	66.50
Grand total	18241	1967	10.7	3597	19.07	201	1.10	2072	11.3	2542	13.9	121	6.8	100	.50	2306	12.6	10993	60.40

Check Plat, Trees 12, 14, 17, 18. Varieties: Ben Davis, Jonathan.

	Total No.	Codling-moth	Per cent	Curculio	Per cent	Scab	Per cent	Apple blotch	Per cent	Sooty blotch	Per cent	Bitter rot	Per cent	Black rot	Per cent	Spray injury	Per cent	Sound fruit	Per cent
Windfalls	5606	840	14.9	5071	90.40	38	.60	665	11.8	98	1.7	1389	24.5	46	.80	......	......	356	6.10
Picked fruit	1192	513	43.0	460	38.50	26	2.10	71	5.9	65	15.4	181	15.1	.....	......	......	......	55	4.60
Grand total	6798	1353	19.9	5531	81.30	64	.90	736	10.8	163	2.3	1570	23.0	46	60	......	......	411	6.04

Spraying Results, Orchard of J. T. Tredway, La Harpe, Kansas, 1910.

Bordeaux Plat, Trees 1-6. Varieties: York Imperial, Ben Davis, Winesap, Missouri Pippin.

	Total No.	Codling-moth	Per cent	Curculio	Per cent	Scab	Per cent	Apple blotch	Per cent	Sooty blotch	Per cent	Bitter rot	Per cent	Black rot	Per cent	Spray injury	Per cent	Sound fruit	Per cent
Windfalls	5816	1344	23.1	1039	17.80	30	.50	1432	24.4	......	......	1176	20.2	162	2.70	533	9.1	1810	31.10
Picked fruit	11713	1013	8.6	1787	15.20	......	.....	1892	16.1	261	2.2	409	3.4	......	......	3147	26.7	8552	73.00
Grand total	17529	2357	13.4	2826	16.00	30	.17	3324	19.1	261	1.4	1585	9.0	162	.90	3680	20.9	10362	59.50

Check Plat, Trees 7-12. Varieties: Red Winter Sweet, Winesap, Ralls Genet, Missouri Pippin.

	Total No.	Codling-moth	Per cent	Curculio	Per cent	Scab	Per cent	Apple blotch	Per cent	Sooty blotch	Per cent	Bitter rot	Per cent	Black rot	Per cent	Spray injury	Per cent	Sound fruit	Per cent
Windfalls	8624	3430	39.7	3091	35.8	744	8.6	1662	19.2	20	.2	1072	12.3	196	2.2	......	......	387	4.4
Picked fruit	7070	1922	27.1	1529	21.4	1500	21.2	646	9.1	2572	36.3	375	5.3	......	......	......	......	2617	37.0
Grand total	15694	5352	34.1	4620	23.0	2214	14.2	2308	14.7	2592	16.5	1447	9.2	196	1.2	......	......	3004	19.1

That the reader may grasp the general effects of this treatment, the percentage of the total yield injured by each species of important insect and fungous disease under Bordeaux, lime-sulphur, and check treatment has been determined and set down in the form of a summary. For example, the total number of apples under Bordeaux treatment has been determined, the total number of apples under Bordeaux treatment which are infested with codling-moth has been determined, and the percentage which the latter is of the former has been worked out. Thus we obtain the following summary:

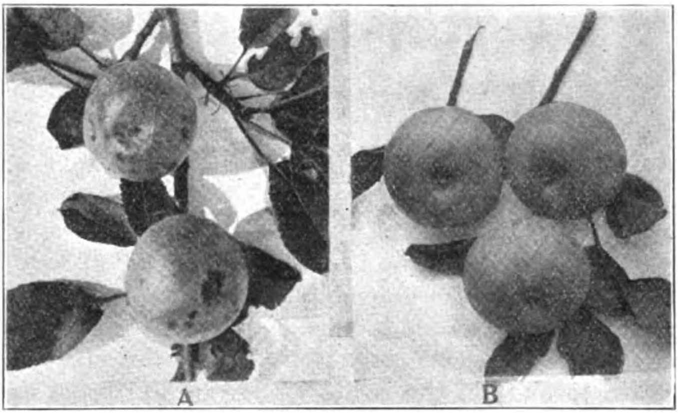

FIG. 11.- Effect of spraying with Bordeaux mixture on apple scab. A. Unsprayed Ingrams badly infested with scab. B. Sprayed Ingrams absolutely free from disease.

INSECT OR DISEASE	Bordeaux, per cent	Lime-sulphur, per cent	Check, per cent
Moth	7.21	5.09	26.80
Curculio	28.97	32.40	52.50
Scab	2.58	1.30	17 98
Apple blotch	7.42	13.35	23.80
Sooty blotch	2.05	4.38	21.35
Bitter rot	4.90	6.34	10.84
Black rot	0 25	1.93	3.01
Spray injury	19.43	4.02	....
Fruit absolutely free from insect and fungous injury	59.60	53.04	12.90

The unsprayed trees showed 26.9 per cent of all the apples which set wormy with codling-moth. The treatment with Bordeaux and arsenate of lead reduced this to 7.2 per cent; while the use of lime-sulphur and arsenate of lead reduced it to 5 per cent. The unsprayed trees showed 52 per cent of all the apples which set injured by curculio. Treatment with the Bordeaux combination reduced this to 28.9 per cent, while treatment with the lime-sulphur reduced it to 32 per cent. The unsprayed trees showed 18 per cent of all fruit which set injured by apple scab. Treatment with

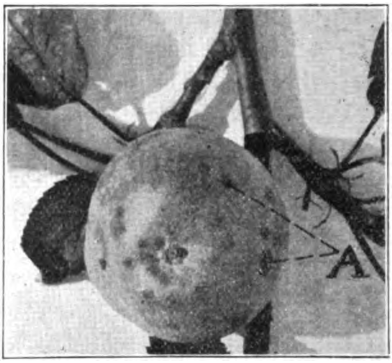

FIG. 12.—"Apple scab appeared on the unsprayed Ingrams and did much harm." A. Scab spot.

the Bordeaux combination reduced this to 2.5 per cent, while the lime-sulphur reduced it to 1.3 per cent. The unsprayed trees showed 23 per cent of all the apples which set injured by apple blotch. Treatment with the Bordeaux combination reduced this to 7.4 per cent, while the lime-sulphur reduced it to 13 per cent.

Feeling that apple blotch is perhaps the most difficult of all of the fungous diseases which the apple orchardist must meet, we determined to find out the relative value of Bordeaux and lime-sulphur in preventing this disease in orchards where it had been sufficiently prevalent for years to destroy practically the entire crop. A block of 156 Missouri Pippin trees, located in the midst of a 100-acre orchard of the same variety, was selected for the experiment. This block was so chosen that each of the rows composing it would be subjected apparently to exactly the same environment, and it was divided into five rows. The first received no treatment whatever, the second was thoroughly sprayed twice

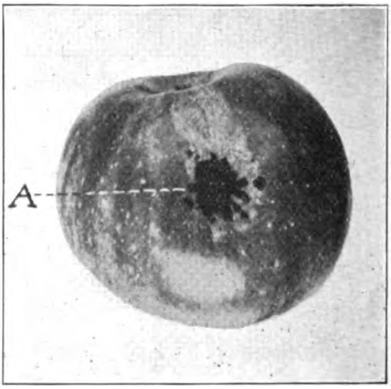

FIG. 13.—"Apple blotch was mainly confined to Missouri Pippins." A. Blotch spot.

with 3-4-50 Bordeaux, the first treatment being given at the dropping of the petals and the second treatment three weeks later. The third was sprayed thoroughly three times with 3-4-50 Bordeaux, the first spray being applied at the dropping of the petals, the second three weeks later, and the third ten weeks after the first. The fifth was sprayed two times with one and one-half gallons of commercial lime-sulphur to fifty gallons of water, the first spray being given at the dropping of the petals and the second three weeks later. The fourth was sprayed three times with one and one-half gallons of commercial lime-sulphur solution to fifty gallons of water, the first being applied at the dropping of the petals, the second three weeks later, and the third ten weeks after the first. In all cases the mixtures were delivered as a mist under a pressure ranging from 120 to 180 pounds with a gas-engine sprayer, and an especial effort was made to give the trees in every case an even and continuous coat. Arsenate of lead at the rate of two pounds to fifty gallons of water was used in the first two sprayings of each row. Although the check received no poison and the commercial results are on that account open to suspicion as being modified by insect injury, careful observation has convinced us that apple blotch is mainly to blame for the low commercial yield of the check. The following tables will show the results of this treatment in commercial returns and in counts made of the individual apples.

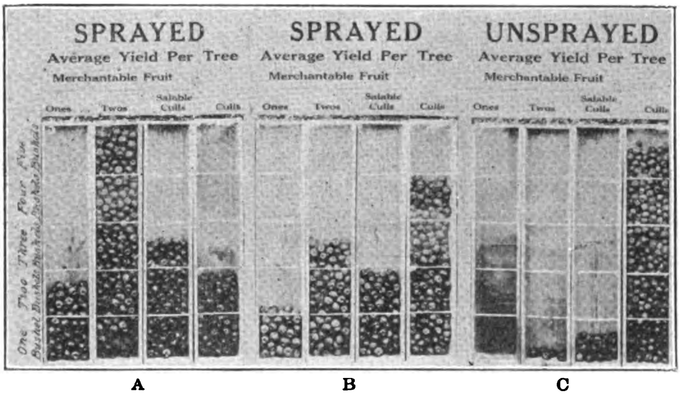

FIG. 14.—Average commercial returns from spraying Missouri Pippins which were located in a hundred-acre orchard badly infested with apple blotch. The poor showing of the unsprayed trees is due to blotch. Late frosts prevented a full set of fruit. A. Sprayed three times with the Bordeaux combination. B. Sprayed three times with the lime-sulphur combination. C. Unsprayed.

Returns in Merchantable Fruit as "Orchard Run."

Row.	Treatment.	Percentage of Merchantable Fruit.
1	None	13.0
2	Bordeaux twice	59.0
3	Bordeaux three times	83.5
5	Lime-sulphur twice	57.0
4	Lime-sulphur three times	57.0

Returns in Merchantable Fruit when graded in 1's, 2's, and Salable Culls.

Row.	Treatment.	Percentage of Merchantable Fruit Which Graded:		
		1's.	2's.	Salable Culls.
1	None	0.0	17.6	82.4
2	Bordeaux twice	3.4	64.4	32.2
3	Bordeaux three times	18.2	54.5	27.3
5	Lime-sulphur twice	5.0	41.8	53.2
4	Lime-sulphur three times	18.8	48.7	32.5

Effect of the Sprays as Determined by Examination of Every Apple Which Set on Each of Four Trees From Each Row.

Row.	Treatment.	Percentage of Apples Free From Apple Blotch.		
		Windfalls.	Picked.	Total.
1	None	11.6	12.6	11.7
2	Bordeaux twice	38.9	52.0	45.1
3	Bordeaux three times	61.6	77.3	72.0
5	Lime-sulphur twice	15.7	20.5	16.5
4	Lime-sulphur three times	25.0	48.8	34.5

Such sprayed fruit as was infested showed fewer and smaller spots than the unsprayed.

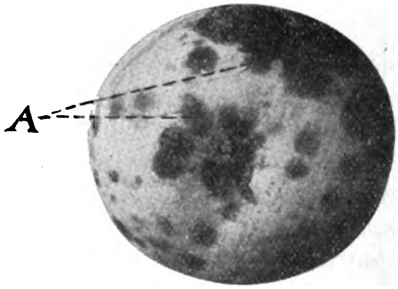

FIG. 15.—"Likewise the work of sooty blotch and fly speck damaged the Ingrams mainly." A. Sooty spots.

Both lime-sulphur and Bordeaux checked the apple blotch materially, even in this badly infested orchard. Three applications are much more satisfactory than two, and Bordeaux is much more effective than lime-sulphur.

Sooty blotch has been satisfactorily controlled by the spraying. Although these sprays were not applied with a view of controlling bitter rot, and were put on too early in the season to be very effect-

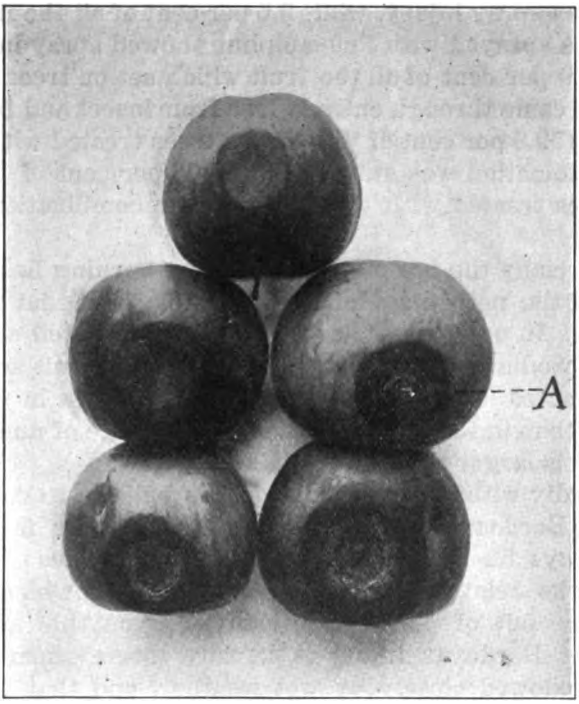

FIG. 16.—"Bitter rot attacked a few of the Jonathan trees." A. One of the rot spots.

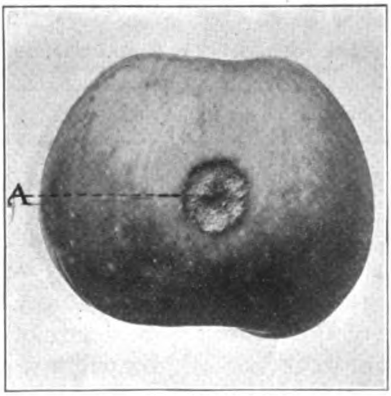

FIG. 17.—"Black rot made its appearance . . . but did little harm." A. Rot spot.

ive, they materially reduced the percentage of fruit injured by this disease. So little black rot appeared that the effect of spraying on this disease was not striking.

Twenty-four and nine-tenths per cent of all the fruit which set on trees sprayed with Bordeaux combination showed more or less spray injury, while 5.6 per cent of all the fruit which set on trees sprayed with lime-sulphur showed spray injury.

Only 12.9 per cent of all the fruit which set on trees that were unsprayed came through entirely free from insect and fungous injury, while 59.6 per cent of that on the trees treated with the Bordeaux combination was uninjured, and 53 per cent of that which set on trees treated with the lime-sulphur combination was untouched.

Commercially the harm from Bordeaux burning lies in the reduction of the percentage of merchantable fruit that will grade number 1. In our experience the Bordeaux treated and burned trees will produce about as much merchantable fruit as the lime-sulphur treated, but the percentage of number 1's in the former is smaller than in the latter, while the percentage of number 2's of the former is larger than that in the latter.

It is hardly within the province of this bulletin to consider the causes of Bordeaux burning, but in view of the fact that its use is always likely to be followed by more or less burning, a few remarks relative to the conditions under which it burns may not be out of place. Previous work on this subject has shown that Bordeaux injury is usually severe when the application is followed closely by wet weather, and that certain varieties are very susceptible to injury while others are almost or quite immune. These findings agree exactly with the experience of the writers. While carrying out orchard spraying as assistant entomologist in the state of New Hampshire, the junior author applied two sprays of Bordeaux and arsenate of lead to MacIntosh Red apples without any resulting injury whatever. Within twenty-four hours after the third application a heavy rain fell and in ten days the damage was very large, the leaves and fruit being badly spotted. Likewise the second treatment of Jonathans at Parker showed (the first was not given) no injury, but within forty-eight hours of the completion of the third treatment a heavy rain came and in two weeks thereafter much burning of fruit and foliage became apparent. As soon after this heavy rain as the sprayer

Relation of varieties to Bordeaux injury observed during the past season.

Almost or quite uninjured.	Injured.
Ingram.	Jonathan. Winesap. Missouri Pippin Ben Davis York Imperial

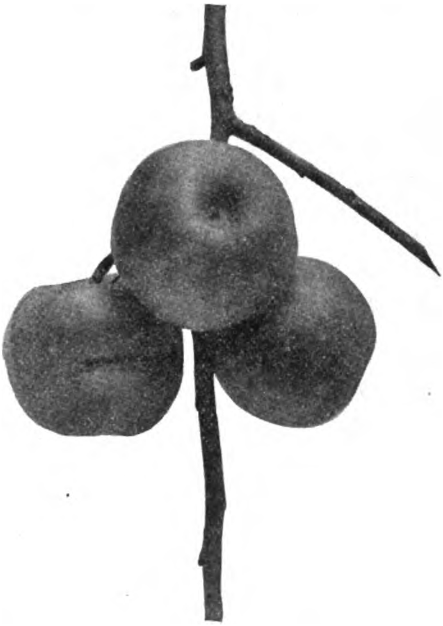

FIG. 18.—Any variety susceptible to Bordeaux injury when treated with Bordeaux is likely to suffer. Missouri Pippins russeted by Bordeaux.

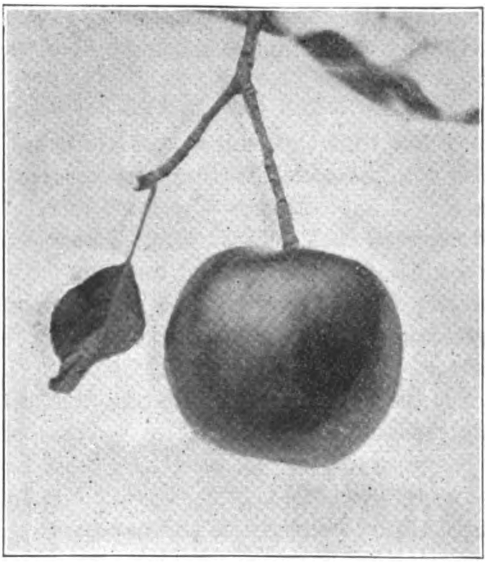

FIG. 19.—Lime-sulphur treated Jonathan.

could be pulled into the orchard the mixed planting at Mildred was treated with Bordeaux, and, not followed by a rain for a week or more, not a trace of burning appeared. Any variety susceptible to Bordeaux injury treated with Bordeaux mixture is very likely to suffer. The preceding table and summary clearly show that all ordinary diseases except apple blotch are almost as well, equally well, or better controlled by use of lime-sulphur than by Bordeaux mixture. Why, then, should not lime-sulphur be used on all varieties susceptible to Bordeaux injury and not likely to be seriously attacked by blotch? Why not use lime-sulphur on Jonathan, Ben Davis, and Winesap? The greater efficiency of Bordeaux in the control of apple blotch and the susceptibility of the Missouri Pippin to the attack of blotch would render the use of Bordeaux on this variety advisable, although burning may result.

Recommendations.

It should go without saying that the orchard from which one expects to get fine apples should be well pruned, well cultivated, and well fed. No amount of spraying will make trees which do not set apples, either because of lack of proper growing conditions or frost, produce fruit. Spraying is intended merely to insure a large percentage of the apples which do set against the ravages of insects and fungous diseases. To render spraying worth while all measures which look toward a strong set of apples must be taken.

NUMBER OF SPRAYS.

In view of the fact that these sprays are intended to destroy fungous diseases which develop throughout the growing season, it appears that at least four sprays should be used and that they should be concentrated at the beginning of the season in such a manner that the foliage and fruit may be covered by a protective substance when the disease spores are sprouting and trying to attack the rapidly growing and consequently tender fruit and foliage. Indeed, when bitter rot is expected, the fourth spraying should consist of either Bordeaux mixture and arsenate of lead, or commercial lime-sulphur and arsenate of lead, instead of merely arsenate of lead.

TIME OF SPRAYING.

There is a right time to spray. The first spraying, which is intended to destroy the apple scab fungus, canker-worms, bud-worms, and leaf-feeders, generally should be applied just after the cluster cups open and just before the flower buds unfold. The second spray, which is intended principally for codling moth and secondarily for curculio and scab and blotch fungi, should be given at the dropping of the blossoms and before the calyx lobes close. This may begin when the blossoms are one-half to two-thirds down. The third spraying, which is intended for codling-moth, curculio, scab, blotch, black and bitter rot, should be given about three weeks after the blossoms fall, because by this time the first brood of codling-moth larvæ is hatching and the fungus-killing mixtures have probably been largely washed from the trees. The fourth spraying, when bitter rot is not anticipated, consists of arsenate of lead alone. It is intended primarily for second brood codling-moth larvæ and secondarily for general leaf and fruit feeders. It should be applied about ten weeks after the blossoms fall.

SPRAYING MACHINERY.

Spraying machinery is intended to deliver the spray mixtures in such a way as to cover the trees thoroughly in the shortest possible time. This is accomplished by placing the liquid under pressure and delivering it through a small aperture whereby it is broken up into a fine mist which can be driven upon all parts of the tree. The first consideration, then, is the power, and the second the pump, the hose, extension rods, and the nozzles.

The power is usually derived from man work, gasoline engine, or compressed air. The first is the cheapest and most practical when less than five hundred trees are concerned, but when 500 to 2000 trees must be treated a gasoline engine is needed, and when more than two thousand trees are to be sprayed compressed air should be employed.

It is quite possible that some growers, owing to scarcity of labor, will find the gas engine most practical for a smaller number of trees than 500. The objection to the gas engine for more than 2000 trees lies in the fact that more than one outfit must be employed, necessitating the employment of an engineer for each, who, if satisfactory, is usually high priced. It is better when several outfits are needed to purchase a good gas or steam engine and a compressor, by means of which an abundance of power can be produced for all outfits. In our experience, spraying done by means of a gas engine outfit when the engine runs well, costs, other things being equal, a little more than one-half as much as when done by hand power. The reduction in cost should be almost as great when compressed air is employed.

Whether the source of power is muscle or gasoline, the spray is put under pressure by means of a force pump. A satisfactory pump, regardless of the power to be employed, should have the following points: (1) all parts that come in contact with the spraying fluid should be made of brass, which will not be corroded by any of them; (2) the air chamber should be so large that the liquid will be delivered in a steady stream, instead of in a succession of spurts; (3) all working parts, especially the valves, should be so made that they can be easily gotten at and cleaned; (4) the parts should be so arranged that they will have the minimum chance of breakage should the pump fall. This applies particularly to the barrel pump, which is always likely to tumble off the wagon or cart, and can best be insured by having a pump the working parts of which are mainly in the barrel; (5) when gas engine is geared to pump, both pump and engine should be immovably fastened upon the same base, preferably of iron or steel.

The hose should be long enough to permit the operator to reach every part of the tree. In our experience twenty-five feet lengths have proven most generally useful. Ordinary garden hose connections are not satisfactory when much pressure is to be employed, because the part which is thrust into the hose is too short and too smooth. Under heavy pressure such connections are likely to slip and make trouble. Hose connections having an especial length and roughness of shaft are desirable. The hose should end in an extension rod of some sort, either bamboo, brass lined, or ordinary gas pipe uncovered. The extension rod should bear one or more nozzles, depending upon the amount of pressure to be used. Two types of spray are used—the strong, dashing type, when the solid stream does not break up for five or six feet after leaving the nozzles, and the mist type, from which the liquid is delivered as a fog. The first type is produced by the Bordeaux nozzle and the second by the Vermorel or "Friend" nozzles. In our experience the "Friend" type of nozzle has proven a little the more satisfactory, because it never catches in the branches of the tree. All joints from pump to nozzle opening should be made so tight that no liquid can escape.

SPRAYING MATERIALS.

We spray the apple orchard to destroy insects and fungi that would, if unchecked, reduce or completely destroy the crop. The insects that do most of the damage to foliage and fruit bite off and consume pieces of fruit and foliage. They can be destroyed by placing a stomach poison at the proper time on the food which they use. Arsenic combined with lead (arsenate of lead) has been found best for this purpose, because it adheres for a long time to fruit and foliage and has so little free arsenious acid in it that we have never known it to burn appreciably.

The important destructive fungi begin their attack on fruit and foliage in the same way. A small spore is blown upon the surface of the fruit or leaf. Under the influence of moisture the spore bursts and a growing sprout emerges. It finds its way through the tissue of the fruit, grows inside the tissue and produces spores which, escaping from the dead tissue, spread the disease to other and healthy tissue. If, while the spore is sprouting, it be brought into contact with a substance deadly to it, it will perish. Of course, this deadly substance must be just strong enough to kill the young fungous-plant and not strong enough to injure the foliage and fruit of the apple. Copper sulphate, or blue vitriol, when combined with milk of lime, forming Bordeaux mixture, has been found to kill the injurious fungi and not very seriously injure the apple. Of recent years, however, accumulated experience has shown beyond doubt that even the weak Bordeaux will, if its application be closely followed by rain, badly burn both the foliage and fruit of certain susceptible varieties. This fact has led to a search for a substitute. Of those tried, lime-sulphur has proven most promising. For all the common apple diseases except apple blotch, lime-sulphur properly used has proven a satisfactory substitute for Bordeaux.

Our experience would lead us to recommend the use of Bordeaux plus arsenate of lead on varieties of apples especially susceptible to blotch, or upon those not subject to Bordeaux injury, and lime-sulphur plus arsenate of lead on varieties not likely to be badly infested by blotch. We would further recommend the 3-4-50 formula for Bordeaux plus two pounds of arsenate of lead, or one and one-half gallons commercial lime-sulphur to fifty gallons of water plus two pounds of arsenate of lead.

METHOD OF APPLICATION.

The method of application should be made to vary with the object to be gained. All sprays except the one given at the dropping of the petals are intended to coat as completely as possible both foliage and fruit with the mixtures. They are therefore delivered as a fine mist from both ground and tower in such a manner as best to effect this object. The spray at the dropping of the petals is intended to fill the open calyx end of the apple with poison, because eighty per cent of the first brood and a large percentage of the second brood of apple worms enter the fruit through this door, and because soon the calyx lobes will roll together, enclosing the poison and holding it there for all comers. When this spray is delivered the young apple stands with the calyx opening upward, and the filling can be best accomplished by shooting the spray into it from above downward under great pressure. There is a difference of opinion among experimenters as to whether the second spray, delivered as a dash, is more effective than if delivered as a mist.

With the ordinary spraying machinery, efficient spraying can not be done with pressure of less than 80 pounds, and the work can be much more satisfactorily and rapidly done with a pressure of 200. Good types of barrel pumps will give pressures ranging from 60 to 120 pounds, with an average of about 80. Gasoline and compressed air sprayers will give pressure from 120 to 225 pounds.

SCHEDULE OF APPLICATIONS.

First application.—Apply as a mist between the opening of the cluster cups and the opening of the blossoms.

Second application.—Apply lime-sulphur as a mist or as a dash, or Bordeaux as a mist at the dropping of the petals and before the calyx closes. Deliver the spray from above downward and make every effort to fill the calyx cup with poison.

Third application.—Apply as a mist about three weeks after the blossoms fall. Apply both from above and below and make every effort to give the fruit and foliage a complete, even coat of the spray.

Fourth application.—Apply as a mist about ten weeks after the blossoms fall. Apply both from above and below and make every effort to give the fruit and foliage a complete, even coating of the spray.

Use 3-4-50 Bordeaux plus two pounds of arsenate of lead for first three sprays on varieties of apples immune from Bordeaux injury or likely to be severely injured by apple blotch. Use one and one-half gallons of prepared lime-sulphur plus two pounds of arsenate of lead to fifty gallons of water for the first three sprayings on varieties susceptible to Bordeaux injury and not likely to be seriously attacked by apple blotch. Make Bordeaux mixture and mix lead and lime-sulphur as described on pages 269-270.

THE FOLLOWING BULLETINS

Are Available for Distribution.

No. 15....Additional Experiments and Observations on Oat Smut.
No. 52....Kansas Weeds—Preliminary Circular on Distribution.
No. 120....Tests of Forest Trees.
No. 121....Treatment and Utilization of Flood-Damaged Lands.
No. 136....Press Bulletins Nos. 125-151.
No. 137....Variations in the Test of Separator Cream.
No. 138....Effect of Bacteria in Wash Water of Butter.
No. 139....The Study of Corn.
No. 140....Milking Machines.
No. 141....Commercial Seeds of Brome-Grass and of English and Kentucky Blue-Grasses: Adulterants and Substitutes and Their Detection.
No. 143....Disposal of Dairy and Farm Sewage, and Water Supply.
No. 144....Small Grains.
No. 148....Law Regulating the Sale of Commercial Fertilizers.
No. 150....The Hen's Place on the Farm.
No. 153....Deterioration of Red Texas Oats in Kansas.
No. 154....The Mound-Building Prairie Ant.
No. 158....Analyses of Registered Feeding Stuffs.
No. 160....Cow-Peas.
No. 162....The Marketing of Eggs.
No. 163....Hog-Cholera and Vaccination.
No. 164....The Selection and Feeding of Laying Hens.
No. 165....Report of State Forester.
No. 166....Spring Grains.
No. 167....A Quantitative Method for the Determination of Hardness in Wheat.
No. 168....The Common Mole.
No. 169 ...Fertilizers and Their Use.
No. 170....Breeding for Type of Kernel in Wheat.
No. 171....Studies on Hog-Cholera.
No. 172....The Pocket-Gopher.
No. 173....Meningo-Encephalitis (Blind Staggers).
No. 174....Milling Tests of Wheat and Baking Tests of Flour.
No. 175....Spraying the Apple Orchard.

Circulars.

No. 1....Treating Seed-Corn to Protect it from Burrowing Animals.
No. 2... Preparing Land for Winter-Wheat.
No. 3....Improved Seed-Wheat.
No. 4....Prairie-Dog Situation.
No. 5....Chinch-Bug.
No. 6....Variety Tests.
No. 7....Corn Ear-Worm.
No. 8....Investigation of the Vitality of Kansas Seed-Corn.
No. 9....Rabies-Hydrophobia.
No. 10....Provisions of the State Forest Law.
No. 11....The Relation of Size, Weight and Density of Kernel to Germination of Wheat.
No. 12....Treatment of Seed-Wheat for Smut.
No. 13....How to Grow Black Walnuts.
No. 14....Contagious Abortion.
No. 16....Burning Chinch-Bugs.

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Kansas State Agricultural College

EXPERIMENT STATION—Bulletin 175

ED. H. WEBSTER, *Director*

FARM BULLETIN

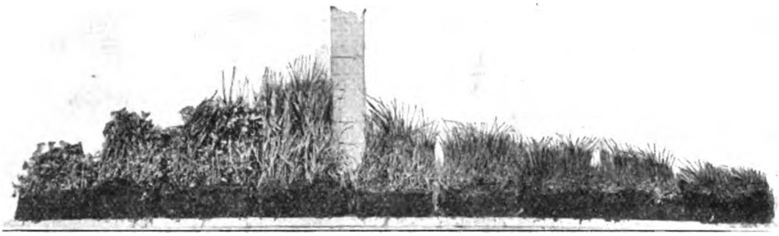

FIG. 1.—Samples of grass taken from variety plots on May 18, 1904, showing relative growthe Numbering from left to right, the names of the samples are: 1. Alsike clover. 2. Medium Red clover. 3. Medium Red clover with *Bromus inermis*. 4. *Bromus inermis*. 5. Timothy. 6. Redtop. 7. Meadow Fescue. 8. Orchard-grass. 9. Italian Rye-grass. All of these grasses were seeded in the spring of 1903.

Department of Agronomy
W. M JARDINE, *Agronomist in Charge*

Grasses

By A. M. TENEYCK,
Superintendent of Fort Hays Branch
Agricultural Experiment Station

MANHATTAN, KANSAS
JANUARY 24, 1911

Kansas State Agricultural College

EXPERIMENT STATION

The Department of Agronomy

W. M JARDINE	Agronomist in Charge
LELAND E. CALL	Assistant in Soils
E. G. SCHAFER	Assistant in Crops
CLARENCE W. NASH	Assistant in Crops
JOE G. LILL	Assistant in Soils
C. F. CHASE	Assistant in Farm Mechanics
BRUCE WILSON	Farm Foreman

Changes in the Personnel of the Department

On July 1, 1910, Prof. A. M. TenEyck, Agronomist in Charge of the Department of Agronomy, was transferred to the Fort Hays Branch Agricultural Experiment Station as superintendent, and in August, Prof. W. M Jardine, formerly of the United States Department of Agriculture, was elected agronomist to fill the vacancy thus created. Mr. E. G. Schafer was elected as Assistant in Crops. Mr. J. G. Lill succeeded Mr. Chas. J. T. Doryland as Assistant in Soils, Mr. Doryland having resigned to take graduate work in the Agricultural College of New Jersey. Mr. C. F. Chase was elected Assistant in Farm Mechanics, and Mr. Bruce Wilson succeeded Mr. Floyd Howard as Farm Foreman. This bulletin was prepared by Professor TenEyck when he was the Professor of Agronomy in this College, but it was not fully completed until after these changes had taken place.

Other Departments of the Agricultural Experiment Station

ANIMAL HUSBANDRY	H. J. Waters in charge
BOTANY	Herbert F. Roberts in charge
BACTERIOLOGY	F. H. Slack in charge
CHEMISTRY	J. T. Willard in charge
DAIRY HUSBANDRY	O. E. Reed in charge
ENTOMOLOGY	Thomas J Headlee in charge
HORTICULTURE	Albert Dickens in charge
VETERINARY SCIENCE	Francis S. Schoenleber in charge

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Grasses

The Value of Grasses

Grass is the fundamental crop. Before the time of man, it covered the surface of the earth with its mantle of green and filled the soil with its thick, fibrous root-growth. Grass thus protected the land from the destructive influences of wind and water, and became also the primary food-supply for a large part of the animal creation. According to the government reports, corn holds the first place among the wealth-producing crops of this country, and grass (hay) takes second rank. It is safe to say, however, that grass is really greater than corn as a wealth producer. The government reports fail to take into account the great wealth produced from grass as pasture; its great value as a soil-protector and soil-renewer; and its power to increase the yield of other crops when used in rotation. Although the native wild grasses grow without the aid of man, it is only when certain species are domesticated and cultivated that the greatest production of hay and pasture is secured.

True Grasses

The grass family (*gramineæ)* includes a number of the most important common farm crops not usually classed as grasses by the agriculturist. The cereal grains, including corn, wheat, oats, barley, rye, etc.; the saccharine and non-saccharine sorghums, including the sorgo (sweet sorghum), Kafir, milo, durra, etc.; and the millets of all varieties, are, botanically speaking, grasses. These crops are grown largely for their grain, but they may be used for hay or pasture. They are then properly classed as forage crops. The true grasses are used principally for meadow and pasture. They are mostly perennial, but include a few annuals also. In this bulletin, the common clovers, though belonging to another family (*Leguminosæ*), will be given some attention, mainly in their relation to grasses in combination meadows and pastures.

Grasses Worthy of Cultivation

It is a surprising fact that, of the thousands of varieties of grasses known to botanists, only a small number are valuable for cultivation. Prof. Thomas Shaw, in his book on "Grasses," names twenty-six varieties which he considers worthy of cultivation, and only nine of these are of major importance as farm crops. These nine grasses are named, in the order of their importance, as follows:

1. Timothy. *Phleum pratense*
2. Kentucky blue-grass. *Poa pratensis*
3. Bermuda grass. *Cynodon dactylon*
4. Orchard-grass. *Dactylis glomerata*
5. Redtop. *Agrostis vulgaris*
6. Russian brome. *Bromus inermis*
7. Meadow fescue. *Festuca pratensis*
8. Tall meadow oat-grass. *Arrhenatherum avenaceum*
9. Meadow-foxtail. *Alopecurus pratensis*

Six minor grasses which have a more or less local adaptation and use are:

1. Quack-grass. *Agropyrum repens*
2. Johnson grass. *Sorghum Halepense*
3. Crab-grass. *Syntherisma Sanguinalis*
4. Western rye-grass. *Agropyron tenerum*
5. Perennial rye-grass. *Lolium perenne*
6. Italian rye-grass. *Lolium Italicum*

Other less important grasses are:

1. Wire-grass. *Carex vulpinoidea*
2. Texas blue-grass. *Poa arachnifera*
3. Rough-stalked meadow-grass. *Poa trivialis*
4. Fowl meadow-grass. *Poa serotina*
5. Rescue-grass. *Bromus unioloides*
6. Sheep's fescue. *Festuca ovina*
7. Carpet-grass. *Paspalum compressum*
8. Velvet-grass. *Holcus lanatus*
9. Australian salt bush. *Atriplex Semibaccata*

Bluejoint (*Calamagrostis Canadensis*) and Blue grama (*Bouteloua oligostachya*) are two promising wild grasses not yet under cultivation.

To the above, the writer would add the following promising Kansas grasses, not yet under cultivation:

3. Big bluestem. *Andropogon furcatus*
4. Little bluestem. *Andropogon scoparius*
5. Buffalo-grass. *Bulbilis dactyloides*
6. Gama-grass. *Tripsacum dactyloides*
7. Indian grass. *Sorghastrum avenaceum*
8. Switch-grass. *Panicum virgatum*
9. Prairie oats. *Atheropogon curtipendulus*
10. Prairie grass. *Koeleria cristata* and *Eatonia obtusata*
11. Short gama. *Bouteloua hirsuta*

Classification According To Use

Meadow Grasses

Grasses may be classed as "tall" and "short." The tall grasses, as the name implies, are those of taller growth, forming sufficient foliage to be mowed for hay. Among the more prominent hay or meadow grasses are timothy, redtop, meadow fescue, Russian brome-grass, meadow-foxtail, Johnson grass, and the several rye and wheat grasses. Western prairie hay is made up largely of such tall-growing wild grasses as big bluestem, little bluestem, Indian grass and the several *Panicums*, such as switch-grass, panic-grass, etc. Various species of *Spartina*, or marsh-grass, gama-grass, and bluejoint, make much of the coarser slough hay of the Middle and Eastern States.

Pasture Grasses

Grasses were first used for grazing. Certain grasses are much more valuable than others for this purpose. According to their habits of growth, grasses may be divided into two general groups: those species or varieties which spread by creeping stems, either above or below ground; and those which grow in tufts or bunches, and which do not spread except by starting new plants from the seed. The creeping grasses are by far the more valuable pasture grasses, since they do not readily "run out," but are rapidly renewed and tend to thicken, covering the ground with a firm, thick sod. Of the bunch-grasses, those that produce leaves largely from the roots or crown are the more valuable for pasture; while the grasses which have a large proportion of leaves on the culm, or stem, are the more valuable for hay or meadow.

While several of the meadow grasses are valuable for pasture, the three distinctively pasture grasses are the Kentucky blue-grass of the Middle and Eastern States, with its Canadian variety in the North; the Bermuda grass of the South; and the buffalo-grasses of the Western Plains, of which there are several important varieties. These grasses are about equally valuable in their respective regions.

Lawn Grasses

Singularly the three great pasture-grasses are also the best lawn grasses in their respective regions. The characteristics of a good lawn grass are the same as those of a good pasture grass. Good lawn grasses should form a beautiful, even green-sward and a firm, thick sod. Lawn grass should not be inclined to produce large stems, but should grow many leaves which lie close to the ground so that it may bear close and frequent clipping. None of the better meadow or hay-producing grasses are suitable for the lawn, because they make a stemmy growth and do not endure close and frequent clipping.

There is no virtue in the peculiar and complex lawn-grass mixtures often recommended by seedsmen, except that Kentucky bluegrass requires the presence of white clover both in lawn and in pasture in order that it may remain permanent and vigorous in growth.

Soil-Binding Grasses

All perennial grasses are soil-binding, even though they do not form a perfect sod, since the soil particles are held in the embrace of the extensive fibrous root system characteristic of all perennial grasses. However, the creeping grasses are the better soil-binders. They hold the soil with their roots, and also form a complete surface-cover which acts as a protection, shielding the soil from the destructive influence of wind and water. The three pasture and lawn grasses named are the great soil-binding grasses. Certain other meadow and pasture grasses, such as *Bromus inermis* and quack-grass, are well adapted for this use, as are also a number of the wild, or native, prairie grasses.

Grasses for Wet Land

The wild marsh-grasses can scarcely be improved upon in the slough and in poorly drained areas. Consequently the breaking of wet land is often a doubtful investment unless such land can be well drained and reclaimed from its swampy condition. However, there is much low land now in cultivation which is not swampy, but which is often too wet to till because it is frequently flooded by heavy rains or by the overflow of streams. Such land may well be seeded in grass and profitably kept either for pasture or for meadow. Grasses are great lovers of moisture, and all the more valuable domestic grasses thrive best on well-watered land. Certain varieties are better adapted than others to wet lands. Chief among these is common redtop, which is valuable both for meadow and for pasture. Timothy and redtop are usually sown together for meadow; and for pasture, other grasses may well be included—meadow fescue, orchard-grass, and Kentucky bluegrass. Alsike clover is better adapted to wet lands than are other clovers. When possible, Alsike should be sown with redtop to improve the quality of the foliage and to increase the permanency and productiveness of the pasture or meadow.

Grasses for Dry Land

There are no dry-land domestic grasses which equal in hardiness the native wild prairie grasses of the western prairies. It is strange that certain of these hardy grasses which are so valuable, even in their wild state, have never been domesticated and improved. None of the domesticated grasses thrive under the more severe dry-land conditions. Certain varieties are much more hardy and productive than others. First among these may be mentioned the *Agropyrons*, or wheat grasses, of which the western rye-grass is the common cultivated variety. The wheat grasses are native of the northwestern states and are well adapted to the warmer climate of Kansas and Oklahoma. Other drouth-resisting grasses are Bermuda grass, tall oat-grass, and *Bromus inermis*. *Bromus inermis* is perhaps best adapted to conditions in western Kansas. Bermuda grass is scarcely hardy in this State, except perhaps in the southern counties. Farther south it becomes one of the most valuable grasses and may thrive even on the dry lands of western Texas and of western Oklahoma.

The farmers of the West have a difficult problem to reclaim for profitable grass production large areas of the drier western lands which have been "cropped" too long with wheat and other grains. None of the domestic grasses fulfill the conditions. It seems to the writer that the solution of this problem lies in the development of our native grasses. In fact, it has been demonstrated already that buffalo-grass may be successfully reëstablished on old, cultivated fields within two or three years, by simply planting pieces of the sod. It is probable that if this grass and other western grasses were grown and bred under favorable cultural conditions for a few years, valuable strains might be secured and propagated.

Experiments With Grasses

For several years a field-test of a number of standard grasses has been carried on at this Station. The first seedings were made in the spring of 1903, and later seedings, both in the spring and in the fall, have been made since that date. However, the results published in Table I are mainly the yields from the original plots seeded in 1903. The trials have been made on the average upland soil of the Experiment Station farm, which, at the beginning of the experiment, was rather lacking in fertility. During the five years, the grass-plots have been given two light dressings of well-rotted barnyard manure, about twelve loads an acre. The manure was applied during the winter and was spread evenly. The land is now much improved in fertility, as shown by the increased yields of hay and by the rank growth of other crops planted on some of the plots after breaking, in 1907 and 1908. The grasses and clovers, and combinations seeded and tested in these experiments, are named in Table I, which gives the date of the first cutting and the annual, and average yield of hay for the several years.

The plots used in this experiment were each one fourth acre in area. The quantity of seed of each grass or combination sown was as nearly as possible the regular amount given in this bulletin. The number of cuttings for hay varied with the grass and with the season. Medium clover made two good cuttings; the second cuttings of mammoth red clover and Alsike were usually light, these varieties tending to head only once. Common alfalfa, Turkestan alfalfa, and sand lucerne yielded regularly four cuttings each per season. In favorable seasons the grasses produced a heavy aftermath, which was cut and cured. The weight of this aftermath added to the crop yield. Usually the second cutting did not amount to much, but in some seasons the yield was considerable. In 1908 the yield amounted to over a ton of cured hay per acre for *Bromus inermis*, and nearly one and one half tons for orchard-grass and for meadow fescue. Most of the grasses head only once in a season and produce regularly one good cutting. Timothy may produce heads twice in the wettest seasons, yielding two good cuttings. A heavy yield of timothy was grown in 1908, the second cutting yielding one and one half tons of good hay per acre.

The yields as given in Table I are comparable for four seasons, 1904-1907, being those of the original plots seeded in 1903, clovers excepted. In 1907, several of the plots were plowed, and the yields for 1908 were in several cases from other plots and from newer seedings.

The yields of hay in 1907 and 1908 were determined as follows: The field-cured hay was weighed as hauled from the field and samples were taken for moisture determination; the yields as reported are for air-dry hay containing fifteen per cent of moisture. In 1904, 1905, and 1906, few moisture determinations were made and the yields given are for field-cured hay, but especial care was taken to have the hay well cured before stacking. However, the moisture-content of hay as stacked often varies greatly, different

TABLE I.—Results of Experiments with Grasses—Comparative Yields of Hay.

NAME OF CROP.	Av. date of 1st cutting.	Average yield per acre in pounds.							
		1904.	1905.	1906.	1907.	1908.	2 yrs., '04-'05.	4 yrs., '04-'07.	4 yrs., '05-'08.
Common alfalfa......	June 7	4488	9720	8380	5900	9704	7104	7122	8426
Turkestan alfalfa.....	June 7	3520	8860	6840	5100	6692	6190	6080	6875
Sand lucerne.........	June 7	seeded	5880	5960	5280	8515	....	....	6434
Medium red clover....	June 18	9420	5740	plowed	3440[3]	winter killed	7580	....	....
Alsike clover..........	June 18	2880	3340	4340	plowed	....	3110	....	....
Mammoth red clover.	July 5	4840	4072	plowed	3760[3]	winter killed	4456	....	....
Bromus inermis[1].......	June 15	4840	2840	2240	1720	5232[7]	3840	2910	3008
Meadow fescue[1]......	June 18	3680	1724	1630	620	4645[7]	2702	1913	2155
Orchard-grass[1]........	June 11	590[2]	1621	1385	1144	7087[7]	1105	1185	2809
Timothy...............	July 5	4530	4901	5393	4293[4]	7526[6]	4715	4779	5528
Redtop................	July 5	3982	2696	1570	plowed	....	3339	....	....
Tall meadow oat-grass......	June 13	1815	1785	1430	1785	4811	1800	1704	2453
Western rye-grass....	July 9	2378	.....[5]	.......[5]	plowed	....	....	....	....
Perennial rye-grass...	June 21	760	1340	plowed	....	....	1050	....	....
Italian rye-grass......	June 21	883	3799	plowed	....	....	2341	....	....
Bromus erectus........	June 10	1844	1720	plowed	....	....	1782	....	....
Kentucky blue-grass..	May 29	seeded	......	2500	1360	plowed	....	....	....
Bromus inermis and medium red clover..	June 14	5580	5740	2780	1480	plowed	5660	3895	....
Bromus inermis and alfalfa[1].............	June 7	5410	6100	6030	4280	9895	5755	5455	6576
Bromus inermis, orchard-grass, and medium red clover..	June 13	5920	4960	2060	2360	plowed	5440	3825	....
Bromus inermis, timothy, and medium red clover...	June 13	5020	5000	2200	2020	plowed	5010	3560	....
Timothy and medium red clover.....	July 4	6360	3664	4100	4293[4]	7373[6]	5012	4604	4857
Meadow fescue and medium red clover..	June 13	6312	4040	1740	plowed	....	5176	....	....
Meadow fescue, orchard-grass, and medium red clover.	June 13	6208	4000	1860	840	plowed	5104	3252	....
Timothy and redtop..	July 5	2178	4356	4074	4293[6]	.......[6]	3267	3725	....

[1] After 1904, average of two plots, one seeded in the spring of 1903 and one in the fall of 1903.

[2] Not comparable with other grass plots on account of poorer soil.

[3] Second seeding on another plot.

[4] Hay from these plots was weighed together, by error, and this is the average yield.

[5] Some foliage, but little stem growth; not cut for hay.

[6] Practically pure timothy in all plots; clover ran out in two years, and redtop does not show.

[7] Newer seedings, except *Bromus inermis*; increased yields due to manuring and favorable season.

samples from different cuttings showing a variation in moisture-content of from fourteen to thirty-six per cent. From the data secured, it appears that well-cured grass hay when stacked usually contains from eighteen to twenty-four per cent of water, while the moisture in alfalfa and clover hay may run a little higher. On the other hand, perfectly air-dry hay may contain as little as ten to twelve per cent of moisture, as shown by actual determinations.

The date of the first cutting varies with the several grasses and with the seasons. With alfalfa, the extremes in first-cutting dates were May 30 in 1903 and June 21 in 1904, a variation of twenty-two days. *Bromus inermis* comes next with a range of twenty days in the dates of maturing. The later-maturing grasses vary least, timothy showing a difference during the five years of only seven days in dates of cutting the first crops. Of the grasses named, orchard-grass matures earliest; *Bromus inermis* is a close second; meadow fescue ranks third; and timothy, fourth. The medium red and Alsike clovers mature for hay with brome-grass and meadow fescue, while mammoth clover and timothy cut well together. Medium red clover matures too quickly to cut well with timothy, but the clover has this advantage, that it makes a rapid second growth after the first cutting. Thus it may produce two good crops of hay in a season, or the second crop may be harvested for seed. In earliness and rankness of growth, *Bromus inermis* ranks first (See Fig. 1 on title-page).

This early starting characteristic, with its spreading habit, makes *Bromus inermis* especially valuable for pasture.

In the average yield for the four years, 1904 to 1907, alfalfa easily ranks first; the combination crop of alfalfa and *Bromus inermis* ranks second; and timothy ranks third. Combinations of grasses with clover, except the combination of clover and timothy, have produced larger yields than has grass alone. The fact that timothy has yielded so well is rather remarkable, but it should be explained that timothy and combinations with timothy were given somewhat the advantage by being planted on the lower and doubtless on the better-watered and more fertile part of the field. The result is valuable, however, although the conditions of growth were more favorable to the timothy, since it proves that timothy will make excellent meadow in central Kansas when grown under favorable conditions.

It will also be observed that timothy is more permanent than the other grasses. The high average yield of timothy continued for each of the five years, while the yields of clover and of all other grasses except alfalfa decreased, usually after the second year. This deterioration is due to various causes: the clovers die in two or three years, meadow fescue gets thinner, and *Bromus inermis* becomes too thick and sod-bound. Orchard-grass, under favorable conditions, may maintain its productiveness for many years and may even improve in stand and increase in yield for three or four years.

It is also worthy of note that, as an average for the first two seasons after seeding, red clover produced a greater yield of hay than did alfalfa. This was due in part to a very favorable year for the clover in 1904, and also to the fact that alfalfa does not reach its maximum production until about the third year after seeding. Medium red clover has yielded better than mammoth red clover or Alsike, largely because of its strong second-crop habit. The other varieties fail to make a second growth in a hot, dry summer.

For the first two crops, the advantage of seeding clover with grasses is very apparent, as shown by the increased yields from all of the combination plots, the *Bromus* with clover proving to be one of the best hay-producing combinations. While the *Bromus*-alfalfa meadow outyields the *Bromus*-clover combination, there are objections to the *Bromus*-alfalfa combination because this crop requires four cuttings the same as alfalfa; also, the last three cuttings are largely alfalfa. The particular value of the *Bromus*-alfalfa combination is for pasture, while for meadow, especially in eastern Kansas, the clover with *Bromus* is preferable. That the newer seedings often have the advantage of older seedings, is shown by comparing the yields from several plots as given in Table II.

TABLE II.—Comparison of Old and New Seedings.

NAME OF GRASS.	Plot No.	Date seeded.	Yield of cured hay, per acre—lbs.				
			1904.	1905.	1906.	1907.	1908.
Bromus inermis	9	1903	4840	2160	1760	1400	Plowed
Bromus inermis	2	1904	....	3460	3200	1040	Plowed
Meadow fescue	3	1903	3680	1880	1900	620	Plowed
Meadow fescue	28	1904	....	4300	1360	400	Plowed
Meadow fescue	21	1906	....	....	....	3800	4645
Orchard-grass	30	1903	590	952	1043	249	Plowed
Orchard-grass	29	1904	....	2290	1728	2040	Plowed
Orchard-grass	20	1906	....	....	....	4000	8884

There should have been no marked difference in the fertility of the plots seeded in 1903 and 1904, but plots 20 and 21 seeded in 1906 had previously grown alfalfa for three years. The yields indicate, also, that orchard-grass may not reach its maximum production until the third or fourth year after seeding.

Adaptation to Soil and Climate

In the study of grasses, their adaptation to soil and climate is often one of the most important factors. Of the first fifteen varieties of cultivated grasses named above, not more than three or four thrive well in any one locality. It is important, therefore, to select and to grow only those varieties of grasses which are best adapted to a certain locality. Whether a grass is well adapted to any locality or not can only be ascertained by an actual trial in the growing of the grass in that locality. Little authentic experimental work has been done along this line in Kansas, with the exception of the recent experiments at this Station, as reported in this bulletin. From these experiments and from the general experience of farmers, we have learned that timothy makes a good hay crop when grown under favorable conditions in the eastern counties of the State; and that south-central and eastern Kansas are especially adapted to the growing of meadow fescue, or English blue-grass, while *Bromus inermis* thrives best in the north-central portion of the State. Clover grows successfully in the eastern counties, while alfalfa is best adapted to the great central portion of the State. The following grasses and combinations of grasses and legumes may be recommended as suitable for meadow and pasture in the several divisions of the State named:

Grasses and Combinations for Meadow

Eastern Kansas

The figures indicate the number of pounds of seed per acre.

1. Timothy (10) and mammoth clover or Alsike clover (6) or medium red clover (8).
2. Orchard-grass (25) and medium red clover (8).
3. *Bromus inermis* (12) and medium red clover (8).
4. Meadow fescue (20) and medium red clover (8).
5. *Bromus inermis* (8), orchard-grass (12), and common red clover (6).
6. Redtop (6), timothy (8), and Alsike clover (4) (for the wetter lands).

Central Kansas

Nos. 2, 3, and 5 above, also Nos. 1 and 4, under the more favorable conditions.

7. *Bromus inermis* (14) and alfalfa (6).

NOTE.—Nos. 1, 2, and 4 are preferable in the south-central part of the State.

Western Kansas

No. 7 as named above.

8. *Bromus inermis* (10), tall meadow oat-grass (12), and alfalfa (6).
9. *Bromus inermis* (18).
10. Tall meadow oat-grass (24).

Combinations of Grasses for Pasture

Eastern Kansas

1. Meadow fescue (10), orchard-grass (10), *Bromus inermis* (8), and medium red clover (6) or Alsike clover (4).
2. Meadow fescue (10), timothy (6), redtop (6), and Alsike clover (4), especially on the wetter lands.
3. *Bromus inermis* (14) and clover (6) or alfalfa (6).
4. Kentucky blue-grass (24) and white clover (4).

Central Kansas

5. *Bromus inermis* (10), orchard-grass (12), western rye-grass (8), and common red clover (6), or alfalfa (6).
6. *Bromus inermis* (16) and alfalfa (6).
7. *Bromus inermis* (20). (*Bromus inermis* cannot be recommended for general planting in southern Kansas.)
8. Meadow fescue (15), orchard-grass (15), and clover (6), or alfalfa (6) (southern Kansas, well watered lands).

Western Kansas

No. 7 as named above.

9. Native prairie grasses.
10. *Bromus inermis* (14), western rye-grass (8), and alfalfa (6).
11. *Bromus inermis* (14) and tall meadow oat-grass (12). (Tall meadow oat-grass is recommended for dry climate and light soil.)

Bermuda grass is not considered fully hardy in Kansas, but it is now being grown successfully in a small way in the southern counties of the State. It is recommended for further trial, especially if the roots for propagation are secured from Kansas fields.

Advantage in Combinations of Grasses

Combinations of grasses and perennial legumes are usually to be preferred to any single grass, both for pasture and for hay. They are especially desirable for pasture, giving more continuous grazing, a greater product, greater variety, and perhaps a better-balanced food ration. In choosing grasses for pasture, the object should be to select such varieties that the deficiencies of one variety may be balanced by the good qualities of another. Another object should be to select those that are different in their periods of growth and in their dates of maturing, so that by lengthening the grazing period, continuous grazing may result. Combinations of grasses may be made which may produce a more perfect sod and a more permanent pasture than is possible for any one grass.

To illustrate, take a combination of orchard-grass, meadow fescue, and *Bromus inermis.* Orchard-grass starts very early in the spring, makes a rapid growth, and matures early in the summer. It produces little during the dry summer months; also, it grows in bunches and does not form a perfect sod. Meadow fescue, on the other hand, starts late in the spring, makes a slow growth in the early part of the season, and matures several weeks later than orchard-grass. Meadow fescue renews its growth in the latter part of the season, making excellent pasture until late in the fall. Like the orchard-grass, it also grows in tufts, but is not quite so bunchy in its manner of growing, so that it forms a much better sod when combined with orchard-grass than does orchard-grass alone. The *Bromus inermis* is quite different in character from either of the other grasses. It starts very early in the spring and usually continues to grow throughout the season. Being a vigorous, deep-rooting grass, it withstands drouth well, and so produces pasture during the dry periods when orchard-grass and meadow fescue practically cease growing. *Bromus inermis* grows until late in the fall, also. It has a habit of spreading by underground root-stalks, and thus fills up the spaces left between the tufts of orchard-grass and meadow fescue, forming a perfect sod. In the region where each of these grasses thrives, the combination of the three should make a better pasture than any one of them alone.

As a rule, a little clover or alfalfa should be seeded with every combination of grasses, whether for meadow or for pasture. The true grasses, so far as science has discovered, take all of their plant-food from the soil, but the legumes, such as clover and alfalfa, utilize the free nitrogen of the air, aided by the bacteria which grow on their roots. Instead of exhausting the nitrogen of the soil, the legumes tend to increase the supply, and act as "feeders" to the nitrogen-exhausting grasses. It is very important, therefore, that every pasture or meadow should contain some perennial legume, because the presence of these nitrogen gatherers not only causes a greater yield of the other grasses, but also makes the soil more fertile for the growing of the other crops. It should be noted here that when combinations of grasses are seeded for meadow, care should be taken that only those varieties are sown together which mature at about the same date, otherwise it will not be possible to produce the largest yield of hay of the best quality. It will be observed that exactly the reverse is true when grasses are combined for the purpose of producing pasture.

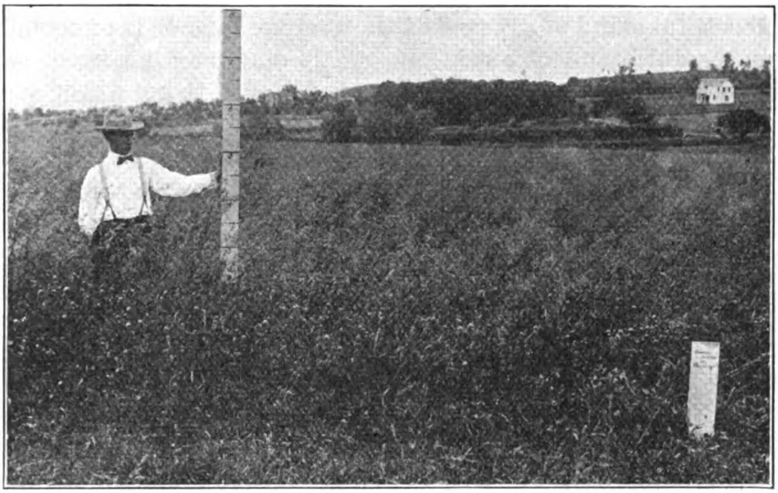

FIG. 2.—A combination crop of Medium Red clover and *Bromus inermis*, June 23, 1904, just before cutting for hay. Seeded in the spring of 1903.

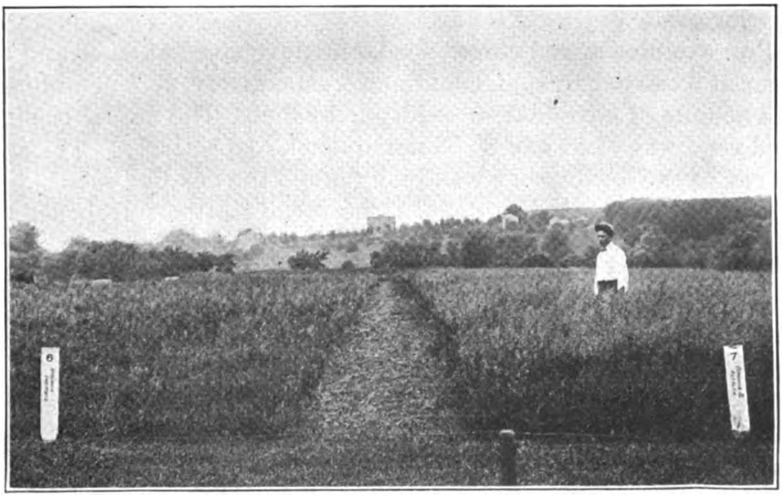

FIG. 3.-Showing plot of *Bromus inermis* seeded with alfalfa on the right and *Bromus inermis* seeded alone on the left. These plots were seeded in the fall of 1903. Photo taken June 7. 1908, just before the grass was cut for hay. Observe the ranker growth of the combination crop and the lesser growth and sod-bound condition of the grass on the plot seeded with *Bromus inermis* alone.

Seeding Grasses

The writer desires to repeat that with good seed, a proper seed-bed, and land adapted for growing alfalfa or grasses adapted to the soil and climate, a careful farmer should be almost as sure of a successful stand of grasses as the average farmer is of securing a successful stand of wheat or oats. Some may not agree with this statement, since many farmers have failed to get a good stand of grasses in a like experiment. Such failures are often due either to poor seed or carelessness in preparing a proper seed-bed.

Good Seed

In order to grow any crop successfully, it is necessary to plant good seed, and this is especially true of grasses, clover, and alfalfa. Grass seed is perhaps more apt to be poor in quality and low in vitality and more mixed with impurities than the seeds of any other crop. It seems hardly necessary to discuss this point, since every farmer knows that he must sow viable seed if he would get a "catch" of grass. But many farmers are careless; much poor seed is sold and sown; and costly failures result. Sometimes it is not possible to purchase first-quality seed of some kinds of grasses, but usually reliable seedsmen sell different grades of grass, alfalfa, or clover seeds, making a lower price for an inferior grade.

Two samples of red clover seed, one purchased at $3.50 and another at $5.50 per bushel, contained, respectively, 27.7 pounds and 55.8 pounds of germinative seed per bushel. The actual cost for good seed was $7.56 and $5.88 per bushel, respectively. The seed offered at the lower price was really much the costlier seed.[1]

In order to save a few dollars, the farmer often purchases the poorer quality of seed, with the result that he may lose money not only by investing in poor seed, but also by planting seed which will be a complete loss. Do not sow poor alfalfa, clover, or grass seed, but purchase the very best grade which the seedsmen have for sale, and test the germination of the seed before planting. It is usually better to delay sowing a year rather than to run the risk of loss by sowing an inferior grade of seed. Several states have passed laws regulating the sale of seeds and requiring a specific guarantee of purity and quality. Until such a law is enacted in this State, the farmers of Kansas must carefully inspect and test the seed as suggested above. If there is any question as to purity, a sample may be sent to the Department of Botany of the State Experiment Station for analysis, and a report secured without charge.

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[1] Farmers' Bulletin No. 111, United States Department of Agriculture.

Germination Test

It is often difficult to judge grass seed as to its vitality. Bright, clean, heavy seed, as a rule, may be safely sown; but the only reliable way to determine its vitality is to test its germination. This can be done by planting the seed out of doors, or in a small box indoors. If the seed is planted indoors, place several folds of wet paper in the bottom of the box, sprinkle the seed over it, and cover it with several folds of wet paper. Close the box and set it in a moderately warm place. Examine the seed at intervals of about three days, and re-moisten the paper if necessary. At the end of seven to fourteen days, the viable seeds will have germinated, and the percentage of germination may be calculated.

A large percentage of germination during the first five to seven days indicates a strong, vigorous seed; while a slow, weak germination indicates seed low in vitality, which may not germinate when planted, except under the most favorable soil conditions. A low percentage of germination, but fairly quick and strong germination, indicates a mixture of good and poor seed; and such seed may be sown, but more seed will be required per acre to insure a stand.

Adulterants and Weed Seed

Grass seed, alfalfa seed, and clover seed should be carefully examined for impurities, and if weed seeds are present, they should be removed before seeding. Cheat or chess, well known as a common grass or weed which grows in wheat fields, is a common adulterant of meadow fescue and *Bromus inermis.* The seed of cheat is larger than meadow fescue seed and smaller than *Bromus inermis* seed, but heavier than either. It usually has short beards or awns at the tip of the seed. Clover and alfalfa seed often contain dodder, which is usually smaller than clover or alfalfa seed and may often be removed by a twenty-mesh sieve. On account of the danger of dodder infection, however, it is usually safest to reject such seed. Other noxious weed seeds common in clover are the narrow-leafed, or "Buckhorn," plantain, and the curled, or sour, dock. Buckhorn seed is boat-shaped, and light brown in color, while dock seed is triangular in shape and reddish brown in color. Both have a smooth, shiny surface.

Timothy seed is usually pure, but old seed may often be mixed with new seed. Orchard-grass seed is sometimes badly adulterated with meadow fescue seed, which is a cheaper seed. Kentucky blue-grass seed is often very weak in vitality, due, in part, to improper methods of harvesting and storing. It is usually pure, but may be mixed with seed of Canadian blue-grass, a similar grass, but much less valuable than Kentucky blue-grass. The extent to which the seeds of these grasses are mixed can be determined only by an expert.[1]

Time of Seeding

Grasses and alfalfa may be seeded either in the spring or in the early fall. Clover should be seeded only in the spring or in the early summer, as fall-seeded clover is very apt to winter-kill. As a general rule, spring seeding for both grass and clover is the safer, although fall seeding has its advantages. If foul land is seeded in the spring, the weeds are apt to grow in such abundance as to smother out the young grass. If such land is sown in the fall, the weeds may do little injury, merely serving as a cover during the winter. If the grass makes a good stand, the crop readily outgrows the weeds the next spring. Again, by spring seeding, practically a season is lost, no crop being produced by the land. If a successful "catch" is secured in the fall, a good crop of hay may be harvested the succeeding year. As a rule, fall seeding of grasses can not be recommended for western Kansas, on account of the prevailing dry winters and windy springs.

Spring seeding is preferable to fall seeding, as it offers more favorable conditions for starting the young plants. Sow all grass and clover seed as early in the spring as the ground can be put in good condition. The common grasses are usually not injured by frost, so that the earlier the seed is sown, the more likely the grass is to start and to make a good stand. In the early seeding of clover and alfalfa, there is some danger of destruction by frost, but, as a rule, the writer prefers to take this chance, rather than that of destruction by hard rains, or by dry or hot weather, to which later seeding is liable. An exception to this general statement may be made for western Kansas and for certain soils or localities, where later seeding may be preferred after the rains come, or when danger of soil blowing is past. In fact, a good general rule to follow in the seeding of grasses or alfalfa, either in the fall or in the spring, is, to prepare the seed-bed early and sow only when the soil is in a favorable condition to germinate the seed. Seeding in dry soil, or in a poorly prepared seed-bed, is very apt to result in failure.

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[1] For further information on impurities and adulterants in grass seeds, see Bulletins 133 and 141 of this Station.

Factors Which Determine Seed Germination and Plant Growth

With viable seed planted in the soil, a few simple factors largely determine the strength of germination, the stand, and the yield of the crop. These factors are *moisture*, *heat*, and *air*. Every farmer knows that a seed will not germinate while it is dry. No matter how favorable other conditions may be, before the processes are begun which produce growth, the seed must absorb moisture. Also, every seed requires a favorable degree of heat before it will germinate, and the presence of air is necessary in order to supply the life-giving oxygen. A seed placed in a vacuum with proper heat and moisture will not germinate. The same results often occur when seeds are planted in a very wet or water-logged soil, because such soil largely excludes the air from the seed.

Understanding the necessary conditions to germinate seed, the farmer may prepare a suitable seed-bed almost any season. Although the methods to be employed for securing an ideal seed-bed may vary with different farmers in different localities, soils, and climates, and no exact rules will apply to all conditions, yet such a seed-bed may be readily described.

The Seed-Bed

Next to good seed, the seed-bed is the most important factor in establishing a good stand of grasses. We have learned that an ideal seed-bed must be warm and moist, and must have the presence of free air in the soil to supply oxygen to the germinating seed and to the roots of the growing plants. It is evident, also, that productive soils supply the necessary amounts of plant-food elements, other than water, which give a balanced food ration to the plant. All fertile soils contain a sufficient supply of the plant-foods—nitrogen, potassium, and phosphorus—but the compounds in which these elements exist are usually in an insoluble condition in the soil—a provision which nature makes to prevent the wasting of plant-food elements and to make possible the fertility and productiveness of the soil for ages.

The plant-food of the soil is gradually made available by the action of weathering agents, which decompose and disintegrate the rock fragments, and by the action of the soil bacteria, which assist in the processes of decay. Chemical changes thus take place by which much of the insoluble and unavailable plant-food of the soil is gradually changed into soluble compounds. In this condition, the plant-foods become available as nutrients to the plant. This change of the plant-food in the soil is favored by the same conditions which are essential for the germination of seeds and the growth of plants; viz., the soil must be warm, moist, and well aerated.

An ideal seed-bed for grasses should not be loosened too deeply. The soil should be mellow, but finely pulverized only about as deep as the seed is sown. Below the seed, the soil should be firm, yet not too hard and compact, making good connection with the deeper subsoil. This offers the most favorable conditions for the germination of the seed and for the growth of the young grass-plants. The firm soil below the seed allows the capillary moisture to be drawn up to the seed, while the mellow soil above acts as a blanket to keep the moisture from escaping, and also allows heat and air to penetrate to the seed. Again, the mulch of mellow soil over the seed not only conserves the soil moisture, but at the same time gives the most favorable conditions for the delicate little plant to push upward into the air and sunshine, while the firm sub-surface soil gives the proper root-hold.

With a deep, loose seed-bed, the conditions for seed germination are less favorable than in the "ideal" seed-bed described. The loose soil may be warm enough and well aerated—perhaps too well aerated, causing the soil to dry out. With the deeply loosened seed-bed, the moisture in the subsoil is not available for the use of the germinating seeds, because the rise of the capillary water is checked at the bottom of the loosened soil. Such a seed-bed is almost wholly dependent upon rain for sufficient moisture to germinate the seed and to start the young plants. In such a seed-bed, the crop is not only apt to "burn out" in summer, but it is also more apt to "freeze out" in the winter than is a crop grown in the "ideal" seed-bed.

Preparing the Seed-bed

It is unwise to seed grass of any kind upon weedy land. Preferably, grasses should follow inter-tilled crops which have been kept well cultivated and clear of weeds, or they may be seeded upon summer-fallowed land which has been cultivated for the whole, or for a part of the season, so as to sprout and to destroy the weed seed in the surface of the soil. Land from which wheat,

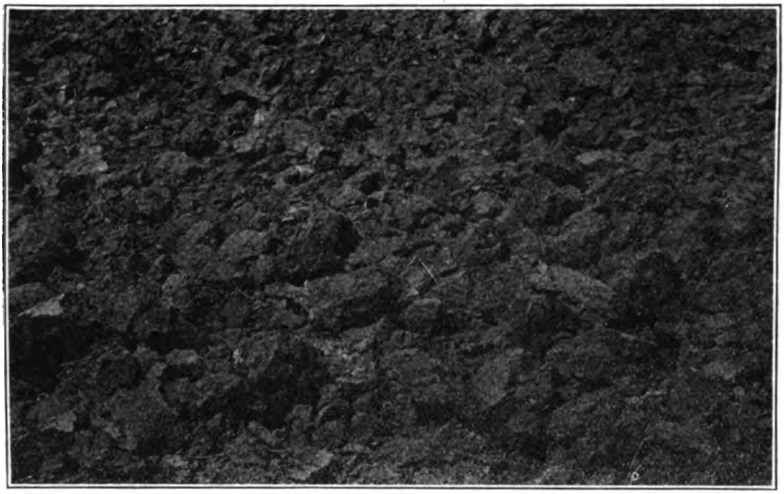

FIG. 4.—Soil in bad physical condition for a seed-bed. This field was plowed late in the spring, when the ground was hard and dry. The field has been disced and harrowed with little effect. It will be impossible to put this seed-bed into good condition until after the lumps have been softened by rain. Photo taken May 7, 1909, Field R., Experiment Station farm.

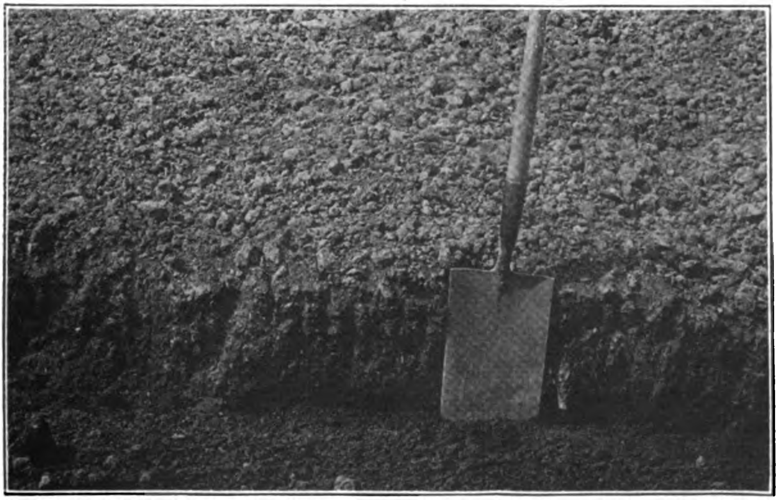

FIG. 5.—A well-prepared seed-bed. This field was plowed early in the spring and well cultivated with the harrow and Acme harrow. Observe the well-settled and well-pulverized condition of the soil and good union between the furrow slice and the subsoil. Photo taken May 7, 1909, Field T, Experiment Station farm.

barley, or oats has been cut, if plowed immediately after harvest, may make a good seed-bed for grass seed, if the soil is kept well cultivated with a harrow or Acme harrow until the weeds have been thoroughly killed and the sub-surface soil has become moist and well settled.

In seeding grasses following cultivated crops which have been kept free from weeds, it is best not to plow in preparing the seed-bed. The weeds have been killed in the surface of the soil, but if the land be plowed, the deeper soil which is brought to the surface will be likely to abound in weed seeds, unless previous careful cultivation has cleared this lower soil of weed seeds. Such land well disked and finely harrowed will give a better seed-bed than can be secured by plowing.

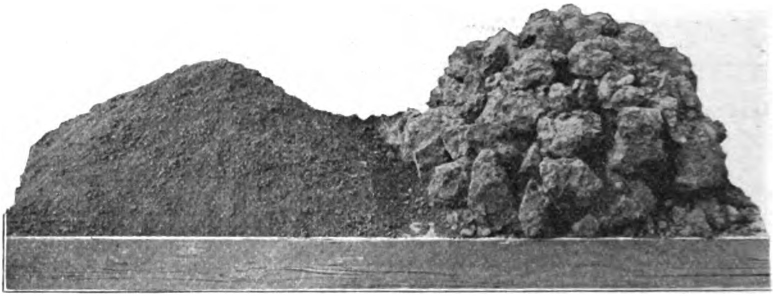

FIG. 6.—Samples of soil taken from Fields T and R, described in Figures 4 and 5. Sample from Field T on the left, showing good texture; sample from Field R on the right, showing cloddy character of seed-bed. Samples taken to the depth of furrow slice, about 5 or 6 inches.

Deep plowing should never immediately precede the sowing of grasses. If the soil needs deep loosening it is well to plow a year or so previous to the seeding, because it is essential that the ground be well settled, and that good capillary connection be established between the furrow-slice and the sub-soil in order to insure the proper germination of the seed and the vigorous growth of the young grass plants.

When a seed-bed for grasses is prepared by plowing, the land should be plowed several weeks or months before seeding time and should be cultivated at intervals to clear it of weeds, to conserve the soil moisture, and to put the soil in the best possible condition. The seed-bed should be finished with a level, mellow surface, but with a rather compact sub-surface, in order that the seed may be evenly covered and brought into close contact with the moist soil. If it is necessary to plow shortly before seeding, the ground should be made firm by the use of a sub-surface packer, or a heavy, pulverizing roller. The disc-harrow may be made to do the work of the sub-surface packer in part by setting the discs rather straight and by weighting the harrow. The packing and pulverizing of the furrow-slice is especially necessary when the soil is plowed dry or when stubble, trash, or manure are plowed under. If the furrow-slice is left loose and unpulverized, the capillary connection of the soil with the sub-soil is largely broken, and the soil water will not rise into the surface soil to supply the germinating seed and to feed the roots of the young plants. As a result, the seed fails to germinate well or the plant is often stunted in growth. In such a seed-bed the crop is apt to "freeze out" or to "burn out."

It is not best to plow under coarse manure or a heavy growth of weeds or stubble in preparing a seed-bed for grasses. If the soil is in good physical condition, a good seed-bed may be prepared by plowing immediately before seeding, provided the soil is repacked and well pulverized as described above; but this is often a more expensive method than the discing or early plowing methods. It is often a good plan to disc the ground previous to plowing. If plowed immediately after discing, the loosened surface is in better condition to reunite readily with the subsoil when the furrow-slice is inverted. If the plowing is delayed, the ground should remain in good condition for plowing for a longer period during dry weather than land which has received no cultivation. Also, the disced surface receives and retains moisture. Hence, it may often be advisable to practice early discing of large areas when early plowing cannot be accomplished.

Seeding

Always have the seed-bed fully prepared before sowing the grass so that little work will have to be done on the ground after seeding. If the seed is sown broadcast, one light harrowing after seeding is usually sufficient to cover the seed properly, and is preferable to several harrowings or to any deep working of the soil after seeding. The harrowing should follow the seeding at once because, under favorable conditions, grass seed germinates very quickly, and a harrowing after germination has begun is apt to destroy many seeds.

Those who are practiced in this art seed successfully almost any grass by hand. When combinations of grasses are seeded, a much more even distribution of seed may be secured by the use of a wheelbarrow seeder, several makes of which are sold on the market. Many kinds of grass seeds may be properly sown by means of the grass-seeder attachments which are usually provided on grain drills and seeders. The revolving broadcast-sower is also quite extensively employed. Often the ordinary grain drill is used in the seeding of meadow fescue and may be used also for seeding other grasses, clover, and alfalfa.

At this Station, we usually have good success with the broadcast method of seeding grasses and alfalfa, using the little wheelbarrow seeder. Grass seed sown early in the spring will often start best when it is barely covered with soil. When seeded with the drill, grass seed or clover seed should not usually be covered with more than one inch of mellow soil; and if the soil is pressed over the seed, a covering of one half inch should be sufficient. Grass or alfalfa seed may be drilled a little deeper in the fall, especially if the seed-bed is rather loose or dry at the surface.

Amount of Seed to Sow

The amount of seed to sow per acre varies with the different grasses and with the purpose for which the crop is to be used, whether to produce seed, pasture, or hay. For the production of seed, it is desirable to have strong, fully-developed plants; hence a smaller quantity of seed should be sown than would ordinarily be sown if the purpose were to produce a meadow. If the purpose is to produce a pasture for immediate use, a larger amount of seed is required than for the production of a meadow. For seed production, some recommend that as little as twelve to fifteen pounds of meadow fescue per acre be sown. The usual amount recommended for seeding is twenty-five pounds an acre. Combinations of grasses should not be sown if the purpose is seed production, as it is usually not easy to separate grass seeds, even if the two or more varieties that are planted together should mature and ripen at the same time.

A good old Scotch neighbor and relative who resided near my boyhood home in Wisconsin, when asked how much clover seed to sow for a good stand, answered, "Weel, in a gude season a very leetle will do, and in a bad season it don't make much difference." But it is the judgment and experience of the writer that, by sowing an average amount of good seed at the right time, in a properly prepared seed-bed, it is possible to secure a successful stand of alfalfa, clover, or almost any other kind of common domestic grass, even in a season unfavorable to these crops.

The following amounts of seed of the several common grasses

that may be grown in this State are recommended for seeding when the purpose is the production of a meadow.

Table III.—Giving the Weight per Bushel and the Amount of Seed to Sow.

VARIETY OF GRASS.	Weight per bushel—pounds.	Amt. clean seed to sow per acre—pounds.
Timothy	45	12
Kentucky blue-grass	14	24
Orchard-grass	14	32
Meadow fescue	24	34
Redtop	14	16
Bromus inermis	14	18
Tall meadow oat-grass	14	24
Johnson grass	25	25
Western rye-grass	20	15
Perennial rye-grass	20	30
Italian rye-grass	20	30
Common red clover	60	12
Mammoth red clover	60	12
Alsike clover	60	10
Alfalfa	60	15
Bokhara, or sweet clover	60	20

When two or more varieties are seeded together, it is usual to seed at a slightly increased rate per acre. The amount of legume seed sown should be greater in proportion to that of the grasses. Thus in the following combination, these amounts may be sown: Orchard-grass, twelve pounds; meadow fescue, ten pounds; *Bromus inermis*, eight pounds; and red clover, six pounds an acre respectively. In such a combination, the clover is really an extra, since it dies out in two or three years, and its place must be taken by the grasses, if a good stand is to be maintained for several years. When combinations of grasses are seeded, it is usually advisable not to mix the seeds of different weight and size, but to sow each kind separately.

Nurse-Crop

In the above discussion, no reference has been made to the use of nurse-crops in seeding grasses. In the middle and eastern states, and even in eastern Kansas, it has been the practice to sow certain grasses and clover with different kinds of grain as nurse-crops. This may be a practical method in regions of plentiful rainfall, but generally throughout Kansas the surer method is to seed alone, or without a nurse-crop, not only alfalfa but also clover and the common grasses adapted for growing in this State. If a nurse-crop is used, the grain should be sown thinner than usual, thus reducing the risk of smothering the young grass or clover with a thick growth of grain.

It is often desirable, should drought prevail or should the grain lodge badly, to cut the nurse-crop as early as possible for hay, rather than to let the grain mature and to run the risk of losing the new seeding. Of all the domestic grasses, perhaps timothy may most safely be seeded with a nurse-crop, either in the fall with wheat or rye, or in the spring with winter-wheat, oats, or barley. A good "catch" of clover may often be secured from early spring seeding of winter-wheat or from a thin seeding of oats.

Often a good "catch" of clover or grass, which has been secured with a nurse-crop, has been killed at harvest time. This may be due to the sudden exposure of the tender, young plants to the hot, bright sunshine. However, it is often possible to select a time for cutting the nurse-crop when the weather is more or less cloudy and the soil moist. Some mow the grain stubble, and young grass or clover, close to the ground immediately after harvest, claiming that the young grass or clover is injured by excessive heat due to the reflection of the sun's rays from the straw or stubble. If the mower follows the harvester, the young plants are protected by the covering of stubble and weeds; also the drying of the soil is prevented to some extent by this mulch. The writer has not performed experiments to test this point.

Treatment After Seeding

After seeding, little more can be done for the new crop the first season than to mow the weeds two or three times to keep them from smothering out the young grass plants. It is best, especially in the early part of the season, not to mow the weeds very closely; raise the sickle-bar from four to six inches high and cut the weeds, but leave the larger part of the foliage of the grass uncut. If the young clover, grass, or alfalfa plants are cut back closely in the early part of their growth, before they have become well rooted, many of the young plants may be injured or destroyed.

Making Hay[1]

It is important to know what grasses are best adapted to grow in a certain locality, and to understand the best method of seeding such crops. Also, the hay should be harvested and saved in such a manner as to secure the largest amount and the best quality of the product. The writer would especially urge the importance of quality in hay. Good quality, as indicated by the bright green color of well-preserved hay, will readily add a dollar or two per ton to the selling price.

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[1] For making alfalfa hay, see bulletin No. 155 of this Station.

Cutting the Hay

The common hay grasses and legumes differ somewhat in the stage of maturity at which each should be cut to make the best quality of hay, and farmers and feeders are learning that this difference in quality means not only a difference in market value but also a difference in feeding value. The stage of maturity at which grass should be harvested, in order to make hay of the best quality, varies somewhat with the different grasses and the use to which the hay is put. A safe rule applicable to all common grasses is to cut the grass just as it is beginning to bloom or just after the bloom has fallen. For cattle and sheep, hay from the early cutting is best, but for horses the later cutting is preferable. When cut in the early stage, grass is sure to make good, clean hay of prime quality, if the hay is cured well. Often a larger weight may be secured by cutting the grass after it becomes more mature, but the quality of the hay is not apt to be so good. If grass is cut when in full bloom the hay is sure to be more or less dusty. The over-mature hay is less palatable to stock and its feeding value per hundred pounds is usually less than the value of that cut at an early stage of maturity.

CLOVER

To make from clover the most palatable hay of the highest feeding value, clover should be cut just when it is in full bloom, with a few of the blossoms turning brown. If it is cut before this stage, the hay will be lighter and more "washy," especially if fed to horses; while if the crop is left until the clover is mature, many of the leaves will be shattered or lost in harvesting. This will be a great loss, for the leaves are the most nutritious part of the clover, as they contain nearly two thirds of the protein in the plant.

TIMOTHY

To make the most palatable hay, timothy should be cut just as it is coming into bloom. When timothy is grown in combination with common red clover, it is necessary to cut the crop early in order to secure the clover before it has become too ripe to make good hay. The hay cut at this stage is best for feeding cattle and sheep. Timothy should not be allowed to stand until in full bloom, since, if cut at this stage, the hay will be dusty and especially objectionable for feeding horses.

To make the best hay for horses, timothy should be cut at the

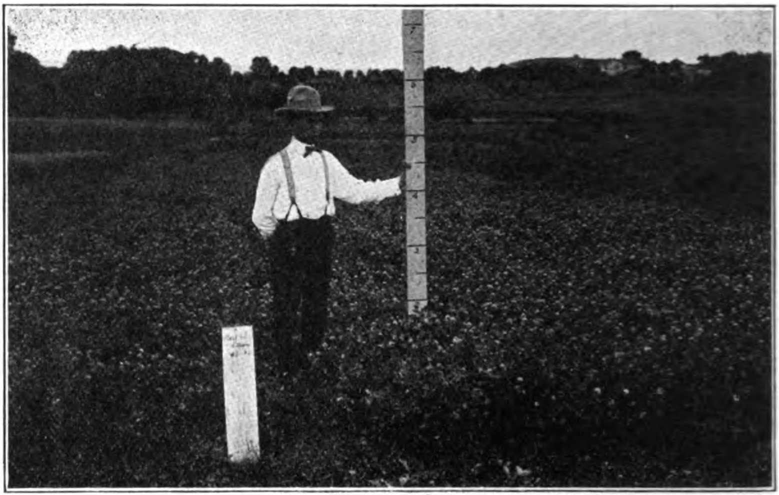

FIG. 7.—Variety plot of Medium Red clover in full bloom, ready to cut. **Photo taken June 23, 1904.** Clover seeded in the spring of 1903.

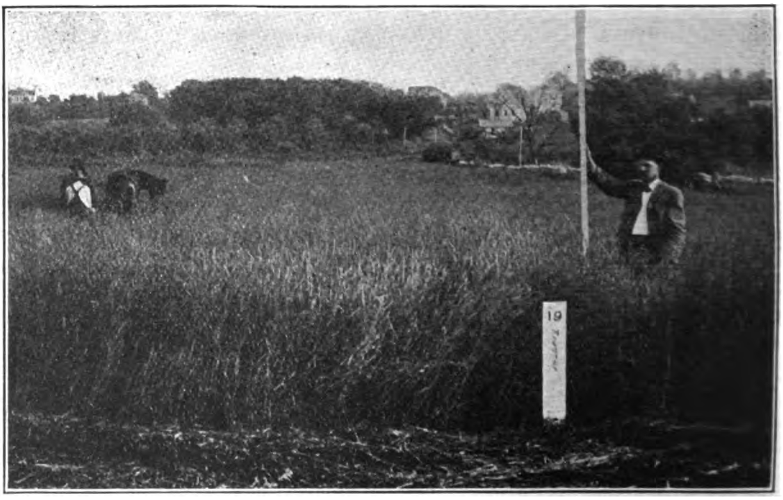

FIG. 8.—Mowing the Timothy plot, July 7, 1909. **This Timothy was seeded in the spring of 1908.**

stage called "second bloom," which is really just when the grass has about ceased blooming and most of the blossoms have fallen. When timothy is cut at this stage, the greatest weight of hay is secured, and probably the greatest amount of nutrients, but the hay is more woody and less palatable than timothy cut earlier.

The maturer hay, however, is relished by horses, and horsemen consider it superior to the less mature hay because less "washy."

OTHER GRASSES

Orchard-grass, western rye-grass, perennial rye-grass, English blue-grass, and Johnson grass quickly lose in palatability when nearing maturity, and should be cut for hay before the blooming stage. Other grasses, such as *Bromus inermis*, redtop, and tall oat-grass, retain their good qualities longer and make good hay if cut when in full bloom or after the blossoming stage. The annual cereal grains, such as barley, oats, and emmer, sowed sorghum, and Kafir, make the best hay if cut when the grain is in the milk or at the soft-dough stage.

MILLET

It is best to cut millet for hay as soon as it is fully headed, before the bloom forms. Cut at this stage, the hay is certainly less woody and more palatable than is the hay made from the more mature millet. The poisonous principle in millet which causes it to be injurious to stock, especially to horses, does not seem to depend upon the condition of the millet with regard to its maturity and the time of cutting. While the less mature millet is better relished, it may seem to give injurious results more quickly.

ANNUAL LEGUMES

Cow-peas should be cut for hay when the first pods are beginning to turn yellow. Soy-beans must not be left so long, but are ready to cut for hay as soon as the pods are well filled. If they are left until too mature, the leaves drop or shatter in harvesting, thus decreasing the palatability and the feeding value of the hay. Field peas and vetches make hay of good quality if cut when the pods are almost fully formed and some of the seed is beginning to ripen.

Curing the Hay

EFFECT OF SUN AND WIND

The most important factor in making good hay is favorable weather. Hay exposed to excessive rains is greatly injured in quality and in feeding value. This is especially true of hay from leguminous plants, such as clover and alfalfa. Every farmer knows that hay is injured by rain and dew, which cause it to bleach and to mould, and which take from it the natural aroma and palatability essential in hay of good quality. Not all are aware, however, that hay which is cured too much in the sun not only bleaches and loses leaves by becoming too dry but also becomes lighter in weight and less palatable.

When one cures hay of any kind, he should aim to expose it to the sun no more than is absolutely necessary. The best hay is therefore made by curing it largely in cocks rather than by leaving it spread over the ground in the swath or windrow. Hay in the swath and windrow is also more exposed to injury by rain and dew than is hay in the cock. Rain not only bleaches hay, thus lowering its market value, but the feeding value of the hay may also be very much decreased. Recent experiments have shown that when partially cured hay is exposed to heavy rain, a large percentage of the soluble substances, including a large part of the proteins, phosphoric acid, potash, and lime, was removed.[1]

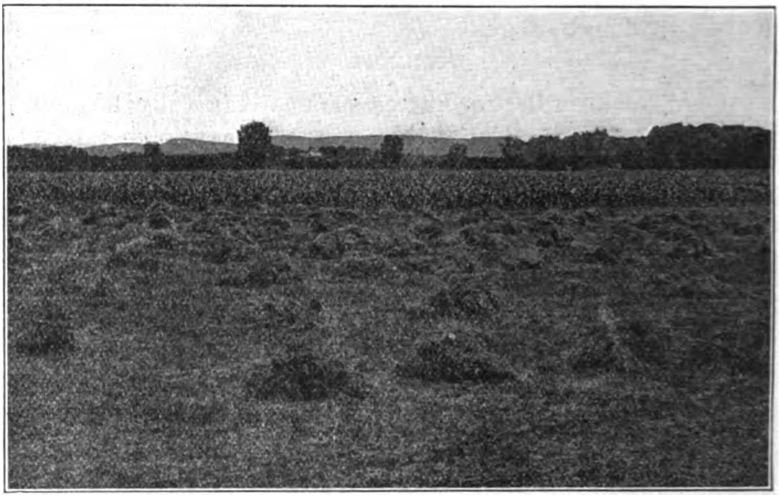

FIG. 9.—Curing alfalfa hay in the bunch. Part of a sixty-acre field on the Experiment Station farm. Second cutting. July 2, 1909.

BUNCHING AND COCKING

Hay cures more evenly in the cock than in the swath or the windrow. If left too long in the swath, the leaves become thoroughly dry, while the stems still retain a large amount of moisture. Such hay will not cure fully and evenly and is often put into the stack in a partly cured condition. If hay is raked before the leaves are dry and placed in cocks, the leaves continue to draw moisture out of the stems, thus allowing the hay to cure evenly.

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[1] Paper read at the annual meeting of the Great Plains Coöperative Experiment Association, August 27, 1908, by J. F. Braezeak, of the United States Department of Agriculture.

Clover or alfalfa hay well cured in the cock in this way will keep perfectly in the stack or in the mow. When cured in the swath and windrow, the hay is often stacked in such condition that it may burn or spoil in the stack. Also, the greater breaking of the leaves which must take place in curing alfalfa or clover in the swath and windrow, makes the hay less palatable to stock, and less nutritious, than hay which has been properly cured.

WINDROW CURING

A large part of the hay made in the United States, however, is cured in the swath and windrow, or in shocks made by bunching the hay with the horse-rake. When a farmer has a large amount of hay to put up and little help with which to handle it, he is compelled to do the work in the most rapid and economical way. Putting up the hay directly from the windrow is not only a saving of labor, but it enables the hay-maker to do the work rapidly so that the danger of loss by exposure to the weather is lessened.

In the Central States it is common to cure timothy and clover hay in the swath and windrow, and to put it on the wagon by means of the hay-loader, which makes the work more rapid and does away with the hard labor of pitching hay. In the large alfalfa and prairie-grass fields of the Western States, the common method is to use sweep-rakes, by which the hay is taken directly from the windrow to the stacker. Where a large amount of hay is made, it is almost necessary to handle the crop by such a method. The method of curing hay in cocks is more applicable to the small farmer and to farmers who live where the market price of hay makes it profitable to handle it in this more expensive way.

Good Methods

The following general suggestions may be given with reference to making clover or alfalfa hay; as soon as the dew is off in the morning, start the mower; when the hay has wilted somewhat, run over it with a tedder if the crop is heavy and needs lifting; after an interval of a few hours, before the leaves have begun to get dry and brittle, rake the hay into windrows. Allow the hay to remain in this condition for a day or two, when it may be put into the stack or mow. If the plan of curing in cocks is followed, the hay should be placed in small cocks soon after raking. It will be necessary for it to remain in the field for from one to three days of drying weather before it is ready to be put into the stack.

It is possible to start the mower late in the afternoon, cutting until dark, raking the hay the next forenoon, and bunching or cocking as described above. Good hay may be made in this way, since the dew does not blacken the green hay, and even a light rain during the night may not greatly damage it. There is some objection to this method, however, for making clover or alfalfa hay, in that the dew falling on the green hay in the swath seems to favor the development of white mold. Cutting only during the forenoon after the dew is off is perhaps the preferable method, provided the farmer can handle the crop rapidly enough in this way.

Hay is much more likely to be injured by the moisture *on* it than by the moisture *in* it. This should be an invariable rule: *Hay should not be raked or bunched or placed in the stack or mow when there is moisture on it either from dew or from rain.* Such hay is likely to mold in the cock or in the mow and is almost certain to heat, to blacken, or to "burn" in the stack.

Grasses cure much more quickly than do alfalfa and clover. The length of time required for curing grass hay will depend upon the kind of grass, upon the degree of maturity, and upon the weather conditions. In good weather most grass hays may be cut one day and stored the next. It is even possible to cut grass in the forenoon and to put it up in the afternoon.

Because hay requires rapid handling, it is not necessary to cure grass hay in the cock in good weather. In showery weather, however, it is a very good plan to rake the hay somewhat green, to cock it, and to allow it to cure. Grass hay will shed rain much better in the cock than will clover or alfalfa.

Storing Green Hay[1]

Although the methods described above are the safest and the most satisfactory, it is a very common practice to put clover hay into the mow in a partially cured condition, perhaps on the afternoon of the same day the hay is cut. Green or partly-cured clover put into a tight barn will become very hot, but it will not "burn." Such hay may come out in good condition for feeding, but with a brown color which injures the hay for selling on the market. It may be practicable, also, to store clover while green in raised-bottomed sheds, according to the plan which is now being used in this State for storing green alfalfa.

Hay Caps

It is now becoming a common practice in the more humid sections, where the method of farming is intensive rather than extensive, to protect the hay in the field by covering the cocks with canvas or with paper caps. There is little question regarding the practicability and economy of such a practice on small farms, and there is little question also but that the same method may be used profitably when alfalfa and clover are put up on a large scale. The canvas covers are doubtless to be preferred, since they are more durable and are more easily handled than are the paper caps.

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[1] See Kansas Experiment Station Bulletin No. 155, page 245.

Storing the Hay

Hay should be stored in sheds or in barns. Grass hay sheds the rain better than does clover or alfalfa, and may be stored out of doors with little loss, provided the stacks are well made and covered. However, a good hay-shed is a profitable investment on any farm. When hay is fed on the farm, the aim should be to store it in a convenient place so that it may be conveyed to the stock with the least amount of labor. If possible, the hay should be stored, and the live stock should be fed, under the same roof. This will avoid the expense of handling the hay a second time and the loss from the breaking of the leaves and heads.

METHODS

The most rapid way of putting up hay is by the use of sweep-rakes and sweep-stackers, or swinging stackers. This necessitates stacking the hay in the field where it is cut. This method of putting up hay is best adapted to those regions where hay is made on a large scale. On the average farm, the practical method is to load the hay on wagons and to haul it to the stack or mow. The hay is rapidly removed from the load and dumped into the mow or stack by means of the hay-fork or the hay-sling. Slings are often preferable to hay-forks for unloading hay, on account of the cleaner and more rapid work which may be done by the use of the sling. For barn or shed storing, a carrier and track is usually most convenient. For field stacking, some form of hay-poles with the pulley and rope, either with or without the track, is in general use.

Hay should not be stacked on the ground, but on an elevated bottom made of poles and brush. If hay is green or unevenly cured, it is apt to "burn" or spoil when there is no ventilation beneath the stack. Great care should be taken to keep the middle of the stack full so that when the hay settles the stack will shed rain. There is no better grass-covering for stacks than marsh hay. When the stack is finished and topped out, one should not fail to bind on the cover with good hangers of wire attached to stones or heavy sticks of wood. As a rule, canvas or board stack-covers are troublesome and expensive and not to be recommended.

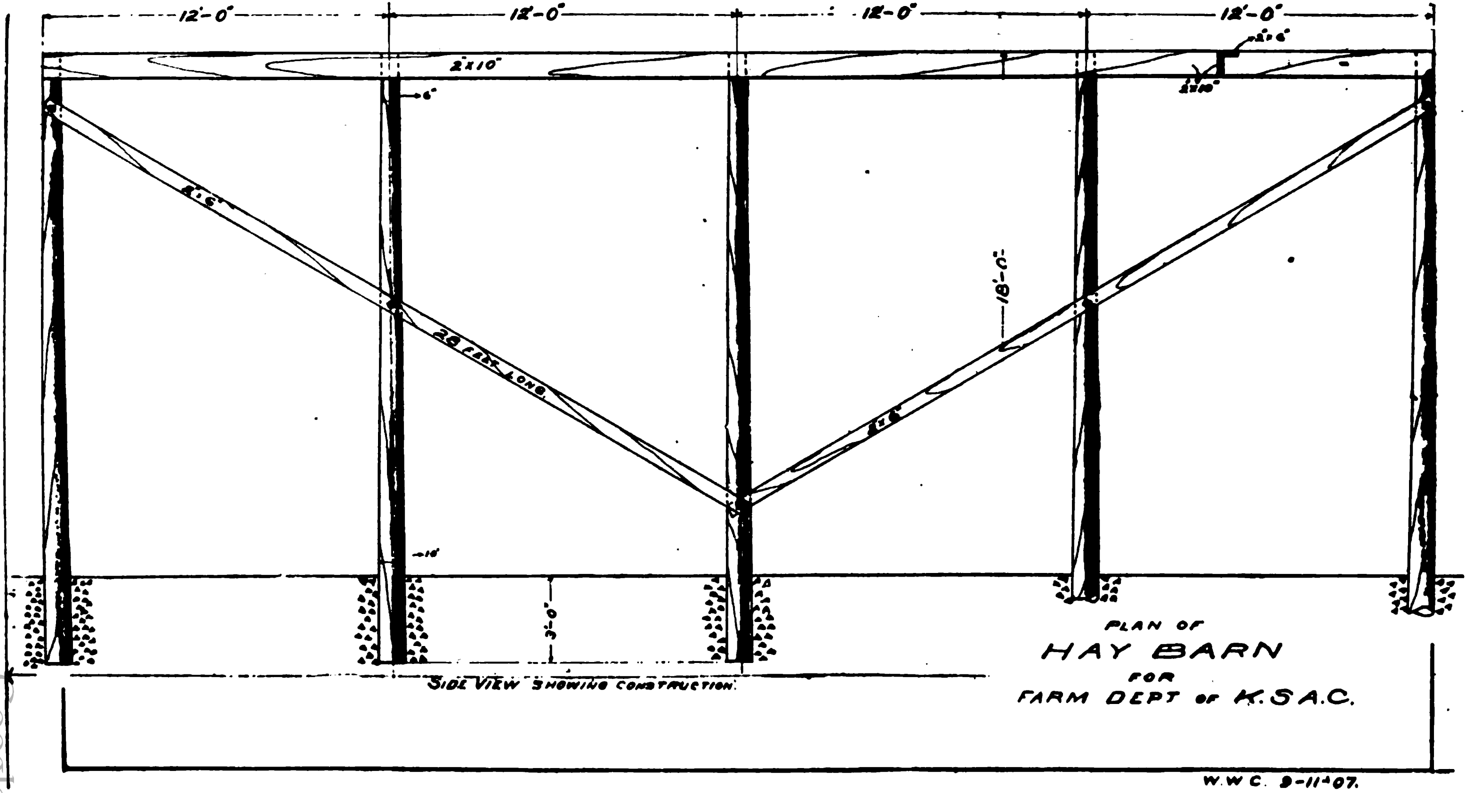

FIG. 10.—Side view of hay barn, showing method of bracing.

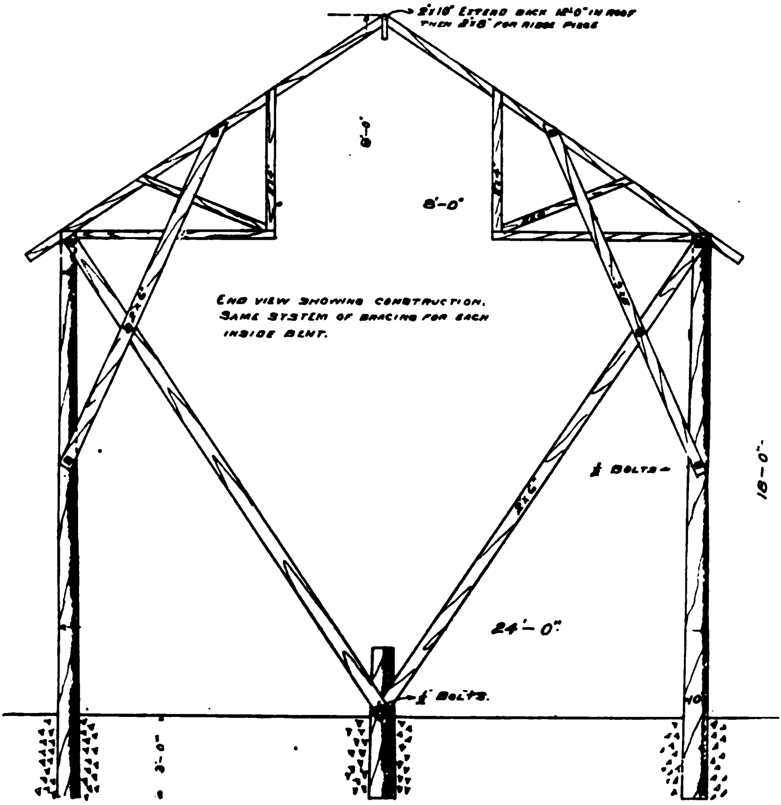
2"x10" Extend back 12'-0" in roof
then 2"x8" for ridge piece
8'-0"
8'-0"
End view showing construction.
Same system of bracing for each
inside bent.
2"x6"
2"x6"
2"x6"
½" Bolts
18'-0"
24'-0"
½" Bolts.
3'-0"

FIG. 11.—Cross-section of hay barn, showing method of bracing.

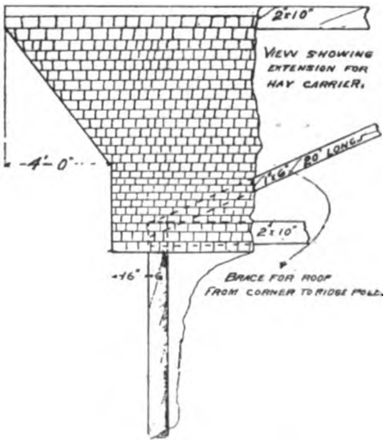

FIG. 12.—Section of roof of hay barn, showing extension for hay carrier track and plan for bracing roof.

A farmer might better build a good hay-shed than use such temporary means of protecting the stacks from rain. It is often advisable to have a canvas cover or two for temporary use when hay is stacked out of doors.

Salting or Liming Hay

It is a common practice in the middle and eastern states to salt the hay when it is put into the stack or mow. In Kansas this practice is not usually followed except by certain farmers who stack alfalfa hay in a green or partially cured condition, and apply salt or lime for the purpose, as they claim, of preventing the hay from heating. There seem to be no sufficient data to prove that the application of lime or salt prevents hay from heating. No work along this line has been reported by experiment stations, and the reports of farmers vary. If the application of salt or lime prevents the heating of green or partially cured hay, this power is probably due to the influence which the salt or lime has in checking the growth of microbes or fungi which cause the fermentation that develops heat. In the same way, lime or salt may prevent the molding of hay.

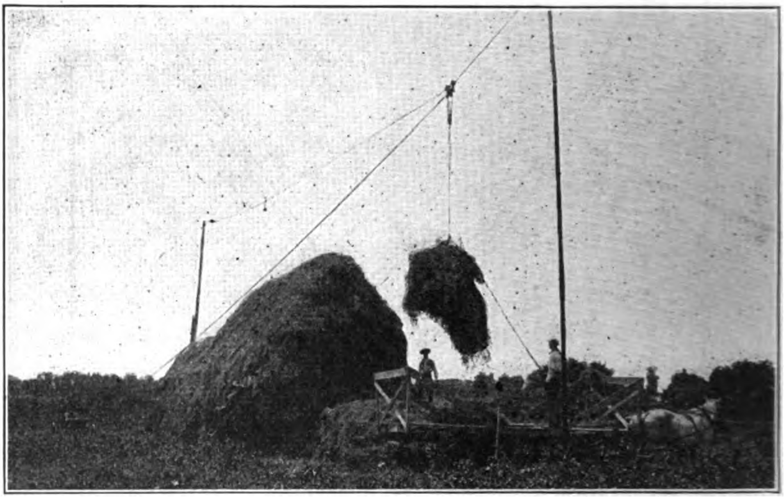

FIG. 13.—Modern methods. Stacking hay with automobile, on farm of W. A. Van Dusen, near Manhattan, Kan.

There is little question but that the salted hay is relished better by stock. The fact that cattle eat the hay with greater relish may be the cause for the opinion among farmers that salting preserves the hay, or makes it keep better. The application of a small amount of salt to the new hay in stacking may be recommended even when hay is well cured. The application of from two to four quarts of salt per ton is usually sufficient, but if the hay is green or only partially cured, more salt may be used. As far as the writer knows, there is no advantage in using lime to prevent the heating of hay, and salt should be preferred, since it adds palatability to the hay. So far as known, no injurious effects result from feeding the limed hay.

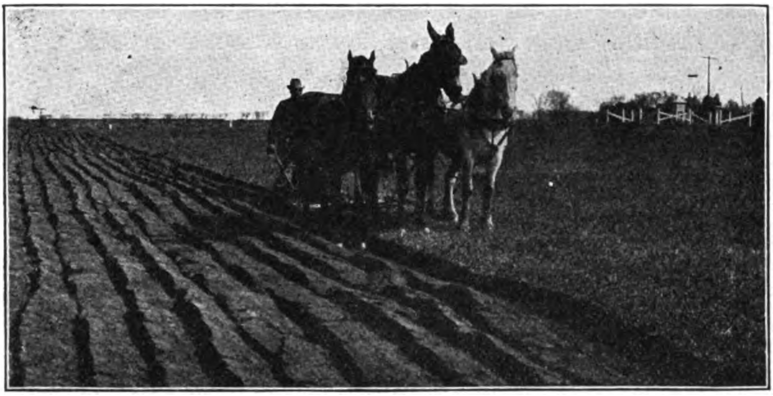

FIG. 14.—Breaking *Bromus inermis* sod on Experiment Station farm five years after seeding. Photograph taken April 3, 1908.

Baling Hay

It is necessary to bale all hay which is sold on the general market. The farmer may sell a little loose hay locally, but loose hay cannot be handled and hauled very far and sold with profit to the grower. Probably the best time to bale hay is in the fall or winter after cool weather has come and when other work is not pressing. Some farmers now bale their hay directly from the field. This is the best time to bale alfalfa, in order to retain the leaves. On the large prairie meadows of the West, this method of handling hay is practical and economical. As a rule,. however, baling hay from the field is too slow a method of putting up hay.

As already explained, it is necessary to harvest hay at the right time and to store it rapidly, in order to secure the best quality. With prairie hay, this matter of time in cutting and making is not so essential as with other grass-hays, or with alfalfa and clover. Baling from the field usually necessitates slower harvesting of the crop, and the work is done at a time when labor is scarce and high-priced. Also, hay baled from the field is perhaps more likely to spoil in the bale than if the hay were first stacked. The new circular power baler (Leubben), with a capacity of from five to ten tons per hour, may solve the question of successful field baling.

BALE CURED HAY ONLY

It has been shown from the experiments conducted at this Station that it is not advisable to bale alfalfa except when the hay is well cured and dry enough to stack. All hay which was baled green or in a partially cured condition spoiled in the bale. Similar experiments in baling clover hay from the field have given similar results. Only well-cured hay may be safely baled[1].

Marketing the Hay

The most profitable way for the farmer to market hay is in the form of horses, beef, pork, mutton, or dairy products. Such products are easily taken to market; and the by-product from feeding the live stock, the manure which may be returned to the soil, may be almost equal in value to the hay itself. Yet some hay must be sold in order to supply the demand for this product.

There is always some local demand for hay. This demand may be supplied by those farmers who produce only a little more hay than is required for feeding on their farms. The farmer who grows hay in larger quantities must seek a market farther from home, and this requires that the hay be baled and shipped to the central markets in the large cities. It is not easy to decide as to just which is the best time to sell hay. Often the price of hay is higher in the latter part of the winter than during the previous months or than it is immediately after the farmer turns the stock out to pasture. In February and March there is likely to be a shortage in the supply of hay. At that time the large grower may often take advantage of the advanced price to gain an additional profit in the sale of his crop. However, the factor which largely determines the price is the quality of the hay. Good hay will always command a fair price, and it has been the aim of the writer in this discussion to call the attention of haymakers to some of the essential factors in the production of good hay.

Shrinkage of Hay

An experiment to determine the shrinkage of hay in the mow was conducted at the Kansas Experiment Station in 1888 by Professors G. H. Failyer and J. T. Willard[2].

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[1] See Bulletin No. 123 of this Station.

[2] See the First Annual Report of the Kansas Experiment Station.

The plan was to fill canvas sacks with several kinds of hay and to bury the sacks in the mow. The weights of the sacks of hay were taken before the hay was stored. The hay of the several kinds was harvested and put into the mow in June, July, and August. On December fifteenth of the same year the sacks were taken out of the mow and the loss in weight determined. Also, moisture determinations were made of samples of hay, both at the time of stacking and when the final weights were taken. The results of the trial are given in table IV:

TABLE IV.—Percentage of Moisture in Samples and Loss in the Mow.

KIND OF HAY.	Per cent. moisture when stored.	Per cent. moisture when taken from mow, Dec. 15.	Per cent. loss in weight.
Orchard-grass, blue-grass, and clover	15.65	10.54	5.71
Blue-grass	19.59	10.60	10.05
Orchard-grass and clover	19.75	11.80	9.01
Millet	21.86	8.89	14.25
Clover	9.08	11.87	3.17[1]
Prairie hay	14.00	10.61	3.39

[1] Gain.

From this experiment, it would appear that the loss in the weight of well-cured hay of the several common grasses, after the hay has been in the mow several months, may vary from three to ten per cent. In the above experiment, it appears that clover actually gained in weight, which must be unusual, since clover is often stacked rather green.

During the season of 1905, the Agronomy Department of this Station made a determination of the moisture in samples of hay of various kinds when the hay was stacked. The samples were from the first cutting, which was harvested in June and July. All of the hay was well cured and stacked in good condition. The moisture in the several samples as determined is given in table V.

TABLE V.—Percentage of Moisture in Well-Cured Hay when Stacked.

KIND OF HAY.	Per cent. moisture when stacked.	KIND OF HAY.	Per cent. moisture when stacked.
Bromus inermis	17.45	Alfalfa	17.3
Meadow fescue	15.09	Medium red clover	14.90
Orchard-grass	15.41	Alsike clover	16.41
Tall meadow oat-grass	13.95	White Bokhara clover	17.78
Italian rye-grass	17.30		

It would appear, from the results of the experiment conducted by Professors Failyer and Willard, that all kinds of hay contain about the same amount of moisture when the hay becomes fully cured in the mow. The average moisture in the mow-dried hay in that experiment, not including the millet, was 11.08 per cent. If this per cent. (11.08) be subtracted from the percentage of moisture found in the hay of various kinds as shown by the 1905 test, it would allow a shrinkage varying from three to six and one half per cent., provided there was no shrinkage other than that due to the loss of moisture.

The testing of the moisture content of the samples of hay when the hay was stacked, was continued by the Agronomy Department in 1908 and 1909. The percentages of moisture found in various kinds of grass hay when stacked are given in table VI. The determinations for 1905 are included.

TABLE VI.—A Comparison of Moisture in Hay as Stacked.

KIND OF HAY.	Percentage of Moisture[1].		
	1905	1908	1909
Timothy	....	26.52	22.00
Bromus inermis	17.45	31.99	38.24
Meadow fescue	15.09	28.13	27.86
Orchard-grass	15.41	32.20	36.07
Tall meadow oat-grass	13.95	31.45	23.92
Average	15.45	30.06	29.62

[1]The percentage given in each case is the average for several determinations.

It is evident that the hay stored in 1908 and 1909 was not fully cured, yet this hay was cured enough to keep when stored in the stack or mow. Hay stored in this condition may readily lose fifteen to twenty per cent. in weight after being put in the mow or stack, due to loss of moisture alone.

The percentage of moisture in alfalfa as stacked, as determined by the Agronomy Department, crop of 1909, is given in table VII.

TABLE VII.—Moisture in Alfalfa when Stacked.

DATE OF CUTTING.	Number of determinations.	
First, June 5	32	30.0
Second, July 3	32	33.5
Third, August 6	32	28.5
Fourth[1], September 30	28	24.0
Average	124	29.0

[1] Crop of 1908.

A number of the samples were fully air-dried in the laboratory before the total moisture was determined. The moisture in the air-dried samples varied from nine to twelve per cent. If this hay became perfectly air-dry in the mow or stack, it would lose from seventeen to twenty per cent. in weight as an average for the four cuttings. Green alfalfa when cut has shown, on an average, about eighty per cent. of moisture at the first cutting and seventy per cent. of moisture at the second cutting.

Men experienced in handling hay usually figure on about twenty per cent loss in the weight of the hay after it is put into the mow. The statement is made, also, that after baling the hay, each bale will shrink from two to five per cent. in weight. As hay is ordinarily stacked on a farm, there is often considerable loss from damage by rains, so that the actual amount of hay taken from a stack may often show a loss considerably greater than that due to the shrinkage in the weight of the hay by loss of moisture. It appears that the amount of moisture retained in cured hay when stacked varies with different kinds of hay and with different conditions of curing. Ordinarily, the loss in weight of hay stacked when well cured and protected from loss other than that which may occur by natural shrinkage, should not be greater than ten to fifteen per cent.

Seed Production

The production of certain grass seeds is confined to limited areas. This is due in part to the fact that grasses do not produce seed equally well everywhere, and also to the special development of the industry in certain localities. A large part of the Kentucky blue-grass seed sold on the market comes from certain counties in Kentucky, Iowa, and Missouri. Meadow fescue seed is produced largely in eastern Kansas, and more extensively in Johnson county than in any other county in the State. Orchard-grass seed is produced largely near Louisville, Ky. The seed of *Bromus inermis* is still largely imported from Hungary and Russia, but this seed is harvested also in northern Nebraska, in North Dakota and in South Dakota. Timothy is grown for seed over a larger area than that of any of the other grasses, but its production on a large scale for market is confined to certain counties in northern and southern Iowa.

Timothy

Timothy will produce good seed in eastern and central Kansas. It is preferable to save and to plant the home-grown seed rather than to sow seed produced in other states, on account of the better adaptation of the crop produced from the acclimated seed. For this reason Kansas-grown seed should be preferred in the culture of other domestic grasses in this State. The slow adaptation of several domestic grasses in this State is due in part to the fact that the new seedings are usually made with imported seed, hence the grass has no chance to become adapted to our different climatic and soil conditions.

Timothy should be cut for seed as soon as the heads turn brown. It is usually harvested with the binder and bound in medium-sized bundles and shocked at once. It should be threshed from the field as soon as the grass is well cured, or it should be stacked and threshed later as may be desired. If timothy is left standing long in the shock, there will be a considerable loss of seed in hauling it. Four bushels per acre is an average yield of timothy seed. Well-saved timothy straw makes fair roughage for horses and mules, but is not relished by other stock.

Meadow Fescue

Meadow fescue ripens quickly after it comes into flower and should be harvested as soon as the heads turn brown. The crop may be harvested with the grain binder and handled in a manner similar to that already described for timothy. A good yield of meadow fescue seed is two hundred to three hundred pounds per acre. The first two or three crops are the most productive for seed. The usual practice is to break up the old sod the third or fourth year and to seed other fields.

Orchard-Grass

Orchard-grass is one of the earliest grasses to bloom and to ripen. Care should be taken not to leave the crop too long before harvesting. When this grass is over-ripe, much seed is lost in handling. The crop may be harvested with the binder and handled as directed for timothy and meadow fescue. Care should be taken in threshing to adjust the fan, since the seed is very light and chaffy and easily lost. It is better to save the seed with a great deal of chaff and to separate it later with the fanning-mill. If stored in large bulk immediately after threshing, orchard-grass seed is apt to heat. The seed should be spread and dried before it is stored in large bulk, or it may be stored safely in sacks. One hundred fifty pounds of orchard-grass seed per acre is a good yield.

Bromus Inermis

Bromus inermis is ready to harvest for seed when the heads assume a deep purplish shade. If left until the heads are brown there will be considerable loss of seed in harvesting. *Bromus inermis* may be cut with a binder and handled in much the same manner as the other grasses named. It is a common practice, however, to cut it high and to bind the stems into sheaves. The seed crop is shocked or removed from the field. The undergrowth is mowed for hay. The crop may also be harvested for seed by mowing and handling loose the same as hay. To avoid shelling the seed, the hay should *not* be handled during the hot, dry portion of the day. Under favorable conditions, three or four hundred pounds of *Bromus inermis* seed per acre is a good crop. The largest yields of seed are secured the first and second years after seeding. This grass does not produce so much or so good a quality of seed in Kansas as it does farther north. The production of seed in this State, however, should be urged in order to secure seed which is better adapted to our climatic conditions than is the northern-grown seed.

Care must be taken in threshing *Bromus inermis* to adjust the fan, since the seed is large and light and easily blown over the sieves. It is better to secure the seed with a large proportion of chaff, which may be readily removed with the fanning-mill. In threshing *Bromus inermis*, use the oat-sieves.

Kentucky Blue-Grass

Kentucky blue-grass is harvested with a stripper. This is simply a box on wheels, with a revolving cylinder in front. The surface of the cylinder is covered with steel spikes. This cylinder revolves rapidly and throws the seed with pieces of the heads into the box. The seed is ready for harvest as soon as the heads turn brown.

Great care must be taken in curing blue-grass seed, since it heats very quickly. This seed must be spread thinly, two to three inches deep, on a drying floor, within a few hours after it is gathered. New seed should be stirred at intervals until it is nearly dry. Then it should be shoveled together into heaps eighteen to twenty inches deep, or it should be stored in sacks. The germinating power of the seed is quickly destroyed by heating. By the ordinary methods of handling, the seed is usually injured in vitality. Ninety-five per cent. of newly harvested seed germinates. Seed purchased in the market is considered good if fifty per cent. of it germinates.

The gathering of Kentucky blue-grass seed in this State can scarcely be recommended as an industry, yet it is advisable for farmers to gather enough seed for their own fields. A farmer may seed a field by mowing blue-grass when it is mature and by spreading the heads and hay over the field. Then the field should be disced to cover the seed. Seed gathered with the stripper may be similarly planted on new fields. The advantages gained by the latter method of seeding are two: The seed planted is of strong vitality; and such seed is best adapted to the soil and climate. This method of seeding may be used also in securing a stand of native bluestem or of other wild prairie grasses.

Clovers

Clovers are more uncertain seed-producing crops than grasses, yet by proper management and under favorable conditions very large yields of clover seed may be secured. Yields of from eight to ten bushels an acre have been reported, but three to four bushels an acre is a good crop. Even two bushels an acre, with clover seed at ordinary prices, will pay for the harvesting and threshing, and will return a fair rental on the land.

The production of clover seed is largely dependent upon the presence of bumblebees or of other bees or insects which have proboscides long enough to reach the nectar in the flower-cups. These insects are largely the agents through which the pollination of the blossoms is effected. It is claimed that the ordinary honey-bee may cause the fertilization of Alsike clover and white clover, but not of red clover and mammoth clover, since the proboscis of the honey-bee is not long enough to reach the nectar in the flowers of the red and of the mammoth clover. Since it may be fertilized by honey-bees, Alsike clover is a greater seed-producer and a more certain crop than red or mammoth clover. The greater seed-producing quality of Alsike clover may also be in part due to a larger number of heads on the plant.

The first crop of Alsike clover or of mammoth clover produces seed. The second growth, if there is any, seldom matures seed. To insure a good seed-crop from Alsike or from mammoth clover, the rankness of growth should usually be reduced somewhat by pasturing it in the spring or by mowing it when the clover has reached a height of from four to eight inches. The grazing or mowing makes the clover mature a little later, and allows for greater fertilization by bees. Even when clover is pastured in the spring, it is advisable to mow it when the grazing ceases, to make it grow more evenly and to kill the weeds. The second crop of medium red clover is much the better seed producer. The first cutting produces little or no seed on account of the absence of the bumble-bees. Under favorable conditions, it is possible to harvest two crops of white clover seed in a season.

Cut clover for seed before it becomes too ripe, when most of the bloom has fallen and when the heads are turning brown.

Alsike clover should be cut when it is a little less mature than medium red clover or than mammoth clover, since Alsike breaks up badly when the heads are fully ripe. The crop is usually harvested with a self-rake reaper or by means of a mower with a buncher, or windrow, attachment. Great loss of seed may result if the mower is run over the cut clover; also, if the clover is raked into windrows with the horse-rake. If clover must be harvested by means of the ordinary mower and horse-rake, mow and rake the clover when the dew is on, or after a light rain.

The best plan is to hull the clover as soon as it is dry, threshing it from the field. It is advisable to turn the gavels or windrows the second or third day after cutting, also after rain, in order to cause the clover to dry and to cure evenly and quickly. The clover huller is much better than the ordinary separator for threshing clover. Some grain separators are equipped with huller attachments which do fairly good work.

It is often desirable to stack clover or to place it in sheds soon after cutting, and to thresh it at a more convenient time. The stack or shed should have a tight floor in order to save the seed, which will usually shell out badly. In loading and stacking clover, much care should be taken to catch the hulled seed. The wagons should have tight-bottomed racks, and a canvas should be spread under the wagon at the stack or shed.

Clover seed should always be carefully fanned and graded for market, since such extra labor and care is amply repaid by an advance in the selling price. Also, care should be taken to keep clover seed pure and free from weed seed. In order to insure clean seed, it is usually necessary to go over the field a few weeks before cutting the clover and to clip off or to dig up the tall weeds. Mowing early in the season tends to destroy weeds, and prevents the grasses growing with the clover from maturing seed. "Saving Alfalfa Seed" is fully discussed in Bulletin No. 155 of this Station.

The Pasture

According to the nature of the plants used, pastures may be divided into annual, temporary, and permanent. Annual pastures must be seeded anew each year and must include such crops as the cereal grains, millet, the sorghums, rape, field peas, vetches, cow-peas, and soy-beans. For hogs, they may also include kale, artichokes, and root-crops. These crops and their use for pasture and forage will be discussed in a separate bulletin on annual forage crops. Temporary pastures are those produced by seeding some of the perennial grasses or combinations of these with clover or alfalfa, with the purpose of using the grass as a crop in rotation with other farm crops. Often the meadow and pasture is combined in one, the grasses being used for hay production for a year or two after seeding, then for pasture. However, since different combinations of grasses are desirable to make the best meadow or the most useful pasture, it is often well to seed separate fields for each purpose.

Permanent pasture is one in which the land is seeded permanently in grass to be used continuously for grazing. This seldom occurs except with native grass lands which are too rough or too stony to be plowed or tilled. The term, "permanent pasture," often refers to the profitable use of pastures for a long period.

When land may be tilled profitably, the temporary pasture is greatly to be preferred to permanent grass land in the West and Middle West, because of the beneficial effect which grasses and legumes have in improving the fertility of the soil. Most of the tame grasses valuable for pasture or meadow are not well suited for permanent pasture, but should be used for temporary pasture or for meadow in rotation with small grains, corn, and other crops.

Experiments with Pasture Grasses

In the spring of 1903, a series of combinations of grasses with clover were seeded in field B on the Experiment Station farm. The field was laid off in six parallel strips, each one hundred feet wide and one hundred sixteen rods long. These strips extended north and south and contained approximately 4.35 acres each. The field had grown cow-peas and soy-beans and corn in 1902. The grass plots crossed the plots of the previous year.

The seed-bed was prepared by discing, "Acmeing," and harrowing, early in the spring. The seeding was accomplished with the Thompson wheelbarrow seeder, between the dates of March 28 and April 6. The brome-grass hopper was used to seed the *Bromus inermis*. The seed was covered by a light harrowing, with the smoothing harrow following the seeder. The seed-bed was in good condition and the weather was exceptionally favorable for seeding and for sprouting the seed. All of the grasses started well, and the clover made a good stand on all plots. The plots were seeded as follows, plot 1 lying on the west side of the field on the highest ground (See table VIII):

Table VIII.—Plan of Seeding Pasture Grasses and Clover in Combination.

PLOT NO.	Grasses seeded.	Amount of seed sown per acre. pounds.
1	Orchard-grass	18.16
	Meadow fescue	16.10
	Medium red clover	4.50
2	Orchard-grass	18.40
	Medium red clover	10.80
3	*Bromus inermis*	18.30
	Meadow fescue	14.00
	Medium red clover	3.50
4	Orchard-grass	19.70
	Bromus inermis	14.60
	Medium red clover	3.70
5	Timothy	8.60
	Bromus inermis	15.00
	Medium red clover	2.80
6	*Bromus inermis*	15.00
	Medium red clover	4.50

This work was started in coöperation with the Animal Husbandry Department of this Station. The purpose was to undertake pasturing experiments in order to compare the productiveness and relative grazing qualities of the several grasses and combinations. However, no definite pasturing experiments have been undertaken. The whole field has been pastured alike with cattle, horses, and sheep, the sheep grazing only during the past two seasons. At times the grass has been very closely cropped, and the pasture has been grazed continuously from early spring until late in the fall. The author has from time to time taken observation notes.

The field was not grazed the first season. The weeds were clipped three or four inches high on June 29, and the grasses and weeds were mowed again late in August, a little clover hay being secured.

The grasses and clover made a good start in the spring of 1904, covering the ground fairly well. The pasture was grazed with cattle and horses early and regularly, but not very closely, during the season of 1904. It was observed that the stock allowed the orchard-grass to form seed-heads, but the plots of *Bromus inermis* were kept closely grazed.

The clover had largely disappeared in the season of 1905, and it did not re-appear to any great extent. Close grazing allowed no seed-heads to form and there was no re-seeding of the clover. The author observed that the orchard-grass was becoming thicker, that the *Bromus inermis* made an excellent sod, while timothy and meadow fescue did not make a good showing. It was evident that the *Bromus inermis* and the orchard-grass were taking the place of the other grasses.

This pasture was given a heavy surface dressing of barnyard manure during the seasons of 1905, 1906, and 1907. The grasses continued to thrive even better than formerly, in 1908 and 1909. On June 11, 1910, a careful observation was made of this field as to the stand and condition of the grasses in the several plots. During that season the pasture was grazed by sheep, cattle, and horses. It was observed that all the plots were well covered with a thick turf except in the gumbo spots. No clover appeared in any of the plots. The percentage of stand of each of the other grasses in each of the plots was estimated as follows (See table IX):

TABLE IX.—Giving Percentage of Stand of Grasses in the Several Plots.

PLOT NO.	Name of Grasses.	Percentage of Stand.
1..........	Meadow fescue Orchard-grass	10 90
2..........	Orchard-grass	100
3..........	Meadow fescue *Bromus inermis*	15 85
4..........	Orchard-grass *Bromus inermis*	50 50
5..........	*Bromus inermis*	100
6..........	*Bromus inermis*	100

It was observed that while all of the plots were closely grazed, plots 3, 5, and 6, containing mostly *Bromus inermis*, were more closely grazed than plots 1, 2, and 4, which were largely orchard-grass. Sheep seemed to graze about equally well on orchard-grass and *Bromus inermis*, and the combination of the two grasses on plot 4 was the best stand of grass and the best pasture. The orchard-grass appeared to stand better on the gumbo spots than did *Bromus inermis*. The combination of orchard-grass and *Bromus inermis* is preferable to either alone. These grasses seem to be about equally persistent, and when combined, are apparently relished more by stock than the orchard-grass alone, are not so closely grazed as the *Bromus inermis* alone, and furnish more grazing in a season. Meadow fescue and timothy seem to be no more productive and much less persistent than orchard-grass and *Bromus inermis*. Meadow fescue and timothy, however, have little value in a combination pasture. This pasture could have been improved by an occasional re-seeding of clover. In this field is a strip of native prairie grass. Observation from year to year indicates that the stock graze less on the native grasses than on the tame grasses. Sheep, especially, preferred the tame grasses and allowed the native prairie grass to make a rank growth in the fall of 1909, while they kept the tame grasses closely cropped. Sheep also graze well on orchard-grass, while cattle and horses relish it much less than they do *Bromus inermis*.

Care and Management of Grass Lands

Renewing the Growth of Grasses in Permanent Meadows and Pastures

The writer recommends the use of the grasses as temporary meadows and pastures in rotation with other crops. When the meadow or pasture decreases in productiveness, the plan should be to break the sod and to grow other crops for a few years before again seeding the field to grass. By this method, larger yields both of grass and of grain crops may be secured apparently without greater exhaustion of soil fertility than may result from continual cropping with grain. In fact, the usual result is that the soil remains more fertile by such a system of rotation. This is due to the protection which the land receives while in grass, to the improvement in soil texture, to the accumulation of humus, and to the extra fertilization by the manuring which occurs from pasturing stock on the grass land. Occasionally, however, it is advisable to keep a field in grass as long as it may be profitably used for this purpose. Low, wet lands, rough or stony lands, and sloping, washy lands are often better adapted to grasses and legumes than to grain crops, hence it is desirable to keep grass growing on such land for long periods.

As meadows and pastures grow old, they become sod-bound and less productive. The available fertility of the soil becomes largely exhausted, and much of it is locked up in the immense root-system which has been developed by the thick growth of the grass. If the field is one which can be used profitably in growing other crops, the best plan is to break the sod and seed new fields to grass. If, however, it is desired to continue the use of the meadow or pasture, a new growth may be secured by partially breaking or by thoroughly discing and harrowing the sod in the spring. This will have the effect of destroying some of the grass roots, which soon decay, furnishing plant-food for the new growth of the grass. Discing also loosens and aerates the soil. This mulch of mellow soil conserves the soil moisture, thus favoring the growth of the grass. Grasses which spread from the root are most successfully renewed in this way.

Manuring and Fertilizing

There is no better fertilizer for grass than farmyard manure. A top dressing applied during the fall or early winter will serve during the winter as a cover to protect the grass roots from the extremes of temperature. As spring opens, the rain carries the nutriment from the manure to the roots of the grass, stimulating an early spring growth, which may continue throughout the season. During the summer, the manure acts as a mulch to keep the moisture in the soil, thus protecting the plants more or less from the influence of drouth.

There is no more convenient place to haul the manure than to the grass land, and there is no crop which responds more readily than grass to the application of manure. It is not necessary to wait until the pasture or meadow is old and worn out before making liberal applications of manure. When the purpose is to plow the sod, the manure should be applied a year previous to the breaking. This will produce larger crops of grass during the season following the application of the manure, and by increasing the root-growth, will add to the humus of the soil, leaving the land more fertile for succeeding crops. Thus the manuring of grass land results in a double benefit, as compared with the manuring of corn or other grain land.

Grazing Meadows

Many farmers turn the live stock into the meadow after harvesting the hay crop, and depend upon the meadow to furnish the late summer or early fall grazing. When there is a vigorous aftermath, and a second crop of hay is not desired, no harm may result from such pasturing. In fact, the grazing may be beneficial, since a heavy mulch of dead grass tends to smother the meadow during the winter or to retard the early growth of grass the next spring. It is not desirable to burn the heavy grass-growth in the spring because burning wastes the nitrogen and exhausts the soil humus. However, it is almost necessary to burn a heavy covering of dead grass because, if left on the ground, it not only checks the new growth, but it interferes with the mowing, and injures the quality of the hay. The meadow should not be grazed too closely or too late in the fall, since late, close grazing will leave the grass with little winter protection and may result in weakening the plants so as greatly to retard their growth the next spring.

Timothy is easily killed by too close grazing, but this is not equally true of all grasses. Permanent pasture grasses, such as Kentucky blue-grass and the wild prairie grasses, may be pastured late in the fall without injury, provided the grass has been allowed to make a vigorous growth in the late summer and early fall. This may often be accomplished on a well-managed farm, by using the meadow aftermath for pasture as described above, allowing the grass in the regular pasture to make a rank growth during the early fall.

Care of Pastures

The productiveness of any pasture grass will be very much reduced by continued close grazing, for the leaves are the lungs and the stomach of the plant. In the leaves, carbon and water from the air, and mineral plant-food elements from the soil, are brought together and, in the presence of sunshine, chlorophyll, and life-giving oxygen, the complex products are made which sustain the life of the plant and cause growth. The bad results of close grazing are especially noticeable in a dry season, but too close grazing at any time weakens the vitality of the plants so that they may not start quickly and vigorously in the spring. Grass should not, as a rule, be pastured the season it is sown. If the season has been very favorable, and if the grass has grown luxuriantly, it may be pastured lightly in the autumn. Close or late grazing should be carefully avoided, because the young plants need their green leaves in order to produce a vigorous root-growth.

Grass becomes less palatable to stock as it matures and forms seed. In order to maintain a fresh, vigorous growth, tame-grass pastures should be mowed before the seed-heads mature. It is advisable also to mow permanent pastures once or twice a year to prevent the seeding of weeds, and to destroy buck brush or other plants that are likely to start in places where the grass has become thin. Grasses in permanent pastures or meadows require more care than those that are grown in rotation with other crops. It is advisable to re-seed permanent pastures occasionally. They must also be fertilized with manure or chemical fertilizers in order to maintain their productiveness. Occasionally, it is advisable to cultivate such grass lands by discing and harrowing early in the spring. The re-seeding and manuring should come preferably at the time of cultivation.

BURNING OFF PASTURES

It is a very common practice in Kansas to burn off the prairie pasture in the spring. In the judgment of the writer this is a useless practice, for by dividing the range and by careful management as suggested above, it is possible to keep the pastures grazed down sufficiently so that they will not require burning. While a heavy growth of dead grass in a pasture is objectionable, a mixture of old and new grass may be preferable to new grass alone for early spring pasture. When cattle are changed abruptly from dry feed to young, green grass, the too-great laxative often causes scouring and the cattle frequently lose in weight for a few weeks. This check in growth may be largely avoided by a judicious mixing of dry feed and green feed, such as may occur if a short growth of dead grass remains in the pasture. It is not advisable to burn a part of the pasture and to leave a part unburned, since the stock will then feed mainly on the burned portion, grazing the young grass very closely. This may result in permanent injury to the pasture, or at least may result in decreasing the amount of grazing for the single season.

RE-ESTABLISHING AN OLD BLUE-GRASS PASTURE

In answer to the question from a farmer in eastern Kansas, "How shall I re-establish an old Kentucky blue-grass pasture?" the author made this answer:

"If you wish to continue the blue-grass pasture as a permanent pasture, I would advise you to re-seed the pasture to Kentucky blue-grass and white clover, with a little Alsike clover. Perhaps the best plan for you to pursue in re-establishing the grass in this old pasture is to disc and harrow the pasture early in the spring, and to plant ten pounds of Kentucky blue-grass seed, two pounds of white clover seed, and four pounds of Alsike clover seed an acre. I would advise you to double-disc the field, cross-discing the second time, then to sow the seed and to harrow twice, so as to level the ground and to cover the seed.

"In order to insure a catch of grass and clover, it may be necessary to keep the stock from this pasture for at least a part of the first season after seeding. I would not advise you to pasture it until the latter part of the summer or early fall. Even then the young grass and clover should not be pastured closely. The cattle should be taken off early in the fall in order that the grass may make a good growth before winter begins. Possibly it is advisable to allow the cattle to run on this pasture early in the season immediately after seeding, in order to firm the soil and to give the seed better opportunities to germinate. Or better still, I would roll the field after seeding, if it seems necessary. However, it may not be necessary to use a roller, since the disc and harrow may put the ground in good seed-bed condition. The soil should not be left too loose and open.

"It would aid in getting a start of new grass on this pasture if you should manure the field during the winter previous to re-seeding. Preferably, give a light dressing of well-rotted manure, ten to twelve tons per acre, evenly spread and mixed with the surface soil by discing and harrowing, as described above.

"If it is not possible for you to secure manure, it may pay to apply commercial fertilizers previous to re-seeding the pasture in the spring. Some of the slaughter-house fertilizers which are rich in nitrogen and phosphoric acid should be preferred. If the land is weedy and a great growth of weeds starts, these should be cut at intervals during the season, to prevent them from seeding, also to prevent injury to the young grass. Bear in mind that it is necessary to give this land a rest from pasturing for a year, or for a part of a year, in order to renew the growth of grass and to make a productive pasture.

"If there is a very poor stand of grass on this old pasture and the land is badly infected with weeds, I would advise you to break up the pasture, provided the field can be plowed and tilled. Crop it a few years, preferably with inter-tilled crops, and then re-seed to grass. If this plan is adopted it will be advisable to sow other grasses with the Kentucky blue-grass and clover. For your section of the State, I would recommend a combination of *Bromus inermis*, orchard-grass, meadow fescue, Kentucky blue-grass, Alsike clover, and white clover. Plant about eight pounds of each kind of grass seed with four or five pounds of Alsike clover seed and a pound or two of white clover seed per acre. The other grasses named in the combination are not so valuable for permanent pasture as Kentucky blue-grass, but they grow much more rapidly at first and so furnish much more grazing for the first two or three years. They will gradually die out and be replaced by the Kentucky blue-grass and white clover. In starting a Kentucky blue-grass pasture, it is often advisable to sow small amounts of other grasses in this way in order to secure an abundance of pasture the first two or three seasons. It will not be advisable, however, to attempt to re-seed the old pasture with the tame grasses named above without breaking up the pasture, since the domesticated grasses will not start well on the sod land. It will not be advisable to plow this pasture with the purpose of re-seeding it the present season."

A similar method may be employed for re-establishing old pastures of native prairie-grasses in central and western Kansas, without breaking the sod. Experiments have shown that old prairie pastures may be renewed simply by manuring, discing, and giving the pasture a year's rest from grazing. In parts of the State, sweet clover (*Melilotus alba*) and Japan clover (*Sespedeza striata*) are being used to renew the fertility and productiveness of old, worn-out prairie pastures. (See the discussion of these clovers.)

Breaking and Cropping Grass Lands

Perhaps the best time to break prairie land, or old, tough sod is late in the spring, in May or June. In the spring, the grass roots are more tender and cut more easily than in the late summer or fall. The soil, too, is usually in good physical condition in the spring, containing sufficient moisture to plow well. If the sod is broken quite late in the spring or early in the summer after the grass is well started, the grass is apt to be killed out better than by fall breaking or by early spring breaking. This more complete killing of the grass by the later breaking is partly due to the hot, dry weather which is likely to occur at that season of the year.

In breaking the prairies of the West, the usual plan is to break late in the spring, and rather shallow—two to four inches deep. After the sod has lain for two or three months, it is back-set or re-plowed a little deeper than the breaking. This turns the tough, partially-rotted sod under and brings to the surface two or three inches of mellow earth in which to plant the seed grain. When this method of breaking is followed, winter-wheat is usually the first crop planted on the new land, and this planting does not take place until several months after the first breaking. This gives time for the decay of the sod, the storing of moisture in the sub-soil, and the preparation of some available plant-food with which to start the new crop.

Some farmers practice breaking a little earlier in the spring, plowing a little deeper and planting at once some late crop, such as millet, Kafir, or cane, perhaps without any preparation of the seed-bed other than plowing or disc-harrowing. Other farmers break the sod in the fall, and, usually without re-plowing, plant early spring crops. Frequently this method of deep breaking and immediate cropping gives unfavorable results. Farmers complain that new land treated in this way, though it may produce a good sod crop, may not produce so well at the second cropping, and occasionally this apparent lack of fertility may continue for several seasons. It is a general opinion among farmers that late fall or early spring breaking injures new land. The writer has carried out experiments in breaking and cropping sod land both at the Kansas Experiment Station and at the North Dakota Experiment Station, the results of which, in part at least, agree with this general experience of the farmers: that the injurious effects on the land are not due to the time or method of breaking, but rather to the immediate cropping of the new land.

The starting of a new crop at once on breaking gives no time for the proper decay of the sod. The moisture in the soil and the rains which fall are largely used by the growing crop, and the sod does not rot; hence there is no accumulation of available plant-food, and the soil remains in bad physical condition. The writer carried on the following interesting experiment at the North Dakota Experiment Station. The sod of a field that had grown a crop of flax was observed to be in dry, hard chunks when it was plowed in the fall after spring breaking. The adjacent plot, broken at the same date but fallowed and cultivated during the summer, was in excellent physical condition when plowed in the fall. The summer-fallowed field gave a much larger yield of wheat.

In my judgment, no injury need come to land from early spring or early fall breaking, or even from very late fall or winter breaking, provided the sod is allowed to decay and to accumulate moisture, so that it may be put into good seed-bed condition by cultivation before a crop is planted. It is often more convenient and more economical for the farmer to break sod in the fall or winter, and if this is done, such land should be disced and harrowed early in the spring, or back-set to prepare a good seed-bed for planting some late crop.

Crops to Follow Grass

It is proper to sow legumes and grasses with crops which thrive in soils well supplied with humus and available nitrogen, such as Indian corn, Kafir, potatoes, and rank-growing forage crops like millet and sorghum. It is not advisable to follow clover, alfalfa, or combinations of legumes and grasses immediately with small grains, since, with an excessive supply of nitrogen, these crops will produce too great a growth of straw, and lodge, and fail to fill well.

With favoring climatic conditions, flax is an excellent crop to grow on old, tough sod, such as native prairie-grass sod, old brome-grass sod, or blue-grass sod.. Certain annual legumes, such as field peas, vetches, and cow-peas, may also be advantageously grown on old sod-land to aid in subduing the sod. These crops often produce well on new land, and they are excellent crops to hasten the decay of sod and to prepare the new land for its second crop. Oats is a strong "feeder" and may produce better on grass-sod land than do other small grains. It is not a safe crop to follow clover or alfalfa, on account of the tendency of the grain to grow too rank and to lodge. When the sod is not so tough but that it may be readily cultivated, an inter-tilled crop, on the breaking, should be preferred to a sowed crop, since by careful cultivation the grass is more completely killed, and the sod is rotted better. Certain grasses, such as Johnson grass, quack-grass, and Bermuda grass, seem to thrive by cultivation and may be an exception to this rule. Such grasses are more readily held in check by smothering-crops, such as millet, cane, and Kafir.

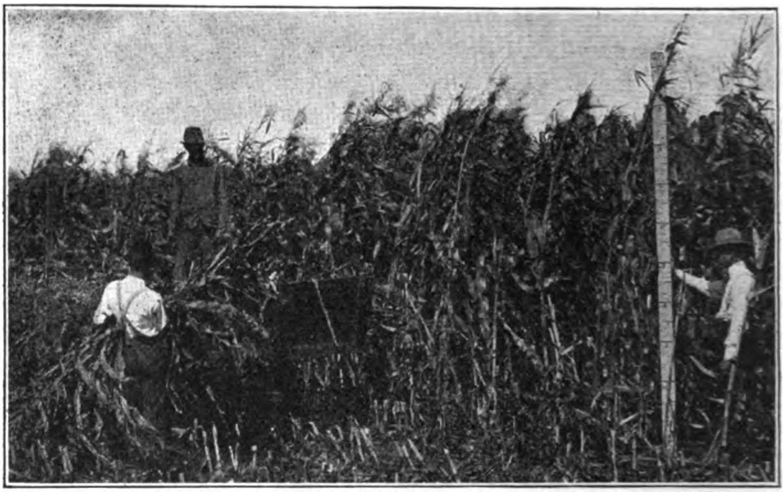

FIG. 15.—First crop on *Bromus inermis* sod which was broken in the fall of 1903. This corn produced over 15 tons of green forage per acre, which was put into the silo. Ordinary land adjacent yielded 8 tons per acre.

Experiments in Breaking and Cropping Prairie Sod

An experiment was carried on at this Station in 1904-1905 to compare spring and fall breaking of native prairie sod, to determine what crops produce well on sod land, and to observe the effect such crops may have on succeeding crops. Twenty-one plots, each twenty-five rods long and two rods wide, and each containing an area of twenty-four hundredths of an acre, were laid off in the summer of 1904 on a piece of high upland prairie pasture on the College farm. The soil in this field was rather shallow and underlaid with limestone at a depth of from three to five feet; hence the field was not very productive, especially in an unfavorable season. The plan of the experiment is briefly given in table X. The sod was plowed at three different times: early in the fall, August 27 to September 3; late in the fall, November 16 and 17; and early in the spring, March 15 to 18. There was no late spring breaking. The breaking was from two and one half inches to five inches deep. One plot of the early fall breaking was back-set late in the fall; other plots received no re-plowing before the planting of the sod crops.

Several plots of flax and a number of other standard crops were planted on this new breaking in the spring of 1905. Four plots were left fallow. Two of these were cultivated to keep down the weeds and on two the weeds were cut once or twice during the season to prevent them from seeding. In the fall of 1905, this series of plots was divided into three equal divisions running crosswise of all the plot series. On the west third of each of the several plots winter-wheat was planted, on November 2, 1905. On the middle third flax was planted, in the spring of 1906; and in the east division corn was planted.

The seed-bed for the 1906 wheat was prepared on all plots by discing and harrowing after the removal of the sod crops as named in the table. The division in which flax seed was planted was plowed in the spring while preparing the seed-bed. In the east third corn was planted with the lister without previous cultivation.

The very late seeding of the wheat, and the thin soil, resulted in a low yield from all plots. Flax did comparatively better than wheat, being a fair crop, but the corn was an inferior crop on all of the plots, and no yield test was recorded. Some of the data on this experiment are tabulated in table X.

From the data in table X it appears that the forage crops and the inter-tilled crops, millet, cane, corn, and Kafir, were the better yielding first crops on sod. Of the small grains, oats and emmer were much superior to barley and spring-wheat in yield. Flax averaged a fair crop, giving rather larger yields from shallow late fall breaking. The "back-setting" and the early fall breaking had a decided effect in reducing the flax yield on plot 11, which gave thirty-eight per cent. less yield than plot 10, adjacent to it, which was not replowed.

The second year's crops, both of flax and of wheat, were noticeably greater on the summer-fallowed plots and after cow-peas. Flax gave larger yields, also, after small grains, millet, corn, and Kafir, than after flax; and the yield of flax after cane was relatively light. Wheat made a relatively good yield after corn, fair yields after Kafir and flax, and very low yields after the small grains, millet, and cane. The writer is well aware that this is not a very satisfactory experiment on account of the light yields, and the results are not conclusive but suggestive of facts as previously discussed in this bulletin and as experienced by many farmers.

TABLE No. X.—A Summary of Results of Experiments in Breaking and Cropping Sod Land.

Plot No.	Date plowed.	Depth plowed, inches.	Crop of 1905.		Crop of 1906.		
			Kind.	Yield, per acre.	Wheat, bu. per acre.	Flax, bu. per acre.	Corn, bu. per acre.
	1905.						Poor crop on all plots - little difference observable—no yields taken.
1	Early spring	5	flax	7.96 bu	8.91	4.66	
2		2½	fallow cultivated		14.30	11.55	
3		2½	fallow not cultivated		14.84	11.79	
4		2½	flax	9.08 bu	10.90	8.12	
	1904.						
5	Early fall	2½	flax	9.07 bu	9.13	8.23	
6		2½	fallow cultivated		14.11	9.56	
7		2½	fallow not cultivated		12.86	11.45	
8		5	flax	7.50 bu	8.09	9.12	
	1904.						
9	Late fall	5	flax	6.03 bu	8.09	10.45	
10		5	flax	9.21 bu	6.95	9.56	
11	[1]	5	flax	5.88 bu	6.43	9.34	
12		5	spring wheat	14.72 bu	3.32	9.78	
13		5	oats	30.97 bu	5.08	11.56	
14		5	barley	11.10 bu	3.84	11.01	
15		5	emmer	30.10 bu	3.58	10.01	
16		5	millet	4333 lbs	4.87	10.56	
17		5	cane[2]	14579 lbs	6.12	9.12	
18		5	cow-peas[2]	4.10 bu	14.21	12.45	
19		5	corn[2]	32.72 bu	10.79	11.12	
20		5	Kafir[2]	13911 lbs. green wt.	9.23	10.34	
21		5	flax		8.92		

[1] Back-set December 22nd, 7 inches deep.

[2] Cane sowed in close drills; cow-peas, corn, and Kafir planted in rows and cultivated.

Grass as a Soil Improver

Formerly the chief crop of the western plains was grass, and grass is still one of the most important crops of the West. On the hills and uplands, where nothing else will grow, buffalo-grass thrives, furnishing pasture for great herds of cattle. In the valleys and more favored locations, bluestem and other native prairie-grasses grow readily, producing thousands of tons of prairie hay annually. The Kansas crop alone averages from five to six million tons a year. For persistency in resisting drouth and unfavorable conditions, no other crop can compare with the native grasses of the western prairies. However, one of the great problems to be solved by western agriculturists is how to handle these grasses so that they may be successfully and economically propagated.

Grass is a soil-protector, a soil-renewer, and a soil-builder. Covering the land with grass is nature's way of restoring fertility to old, worn-out soil. True grasses do not add nitrogen to the soil as do clover and alfalfa, yet they are nitrogen-gatherers. They collect the nitrogen of the soil and store it up in their roots, and by the decay of these roots, humus is formed. Thus grasses prevent the waste of nitrogen and other plant-food elements, protect the soil, and maintain its fertility and tilth. By their extensive and penetrating root-systems may grasses tend to break up and to deepen the soil, thus improving its texture and increasing its moisture-holding capacity. The roots gather the mineral plant-food in the deeper subsoil and store it, in part, in the great fibrous root-growth nearer the surface. This causes an increase in the supply of available plant-food in the soil for the use of more shallow-rooting crops.

When the prairie is first broken, the soil is mellow, moist, and rich, producing abundant crops. After a few years of continuous cultivation, the physical condition of the soil changes; the soil becomes finer grained, more compact, and heavier to handle. It dries out more quickly than sod that is newly broken, and often turns over in hard clods when plowed. This is due to the decay of the grass roots, and to the exhaustion of the soil humus. The grass roots, which separated the soil particles and yet held them together, have decayed, and as a result, the soil tends to run together and become very sticky when wet. When such soil dries, the adhesive character disappears almost entirely, and when loosened by the plow or harrow, it easily drifts or blows away.

The perfect tilth and freedom from clods so characteristic of virgin soils is more or less completely restored whenever land has been sown to grass for a sufficient length of time. After the ground is covered with sod, washing and puddling of the soil by rain is prevented. As the roots grow, the soil particles are wedged apart and rearranged, and thus the mellow, open character of virgin soil is restored. At the same time, through the great growth of the roots, which form humus and accumulate mineral plant-food, the soil is made more fertile for succeeding crops.

The leguminous crops, such as clover and alfalfa, are not equal to grasses as soil protectors, but are superior to grasses as soil fertilizers, since they increase the total available supply of nitrogen in the soil. This is due to the action of bacteria which are found on the roots of leguminous plants, and which take free nitrogen from the air in the soil and make it available for the use of plants. Moreover, perennial legumes, such as clover and alfalfa, are very deep feeders, and take a part of the mineral elements of their food from the soil below the depth of the feeding ground of ordinary crops. Because of their large root-growth in the surface soil, they accumulate a supply of mineral elements of plant-food, which gradually becomes available, as the roots decay, for crops which follow the leguminous crops.

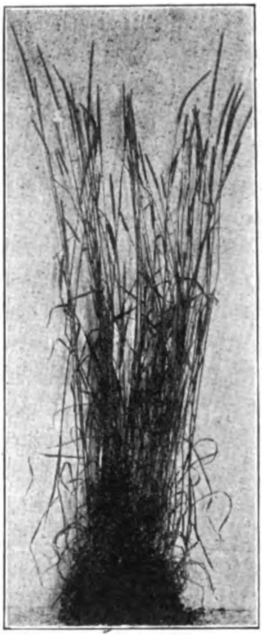

Fig. 16.—Timothy.

Rotation of Crops with Grasses

In order to maintain soil fertility, and at the same time to secure the greatest profit in farming, a practical and scientific rotation of crops should include the following:

1. Grasses and perennial legumes.
2. Pasture, with the addition of manure for one or two years previous to breaking the sod.
3. Inter-tilled crops.
4. Small grain crops, plus green-manuring crops planted in the stubble after harvest.

Small grain crops must be grown on every farm. Often they are the greatest money-making crops; hence they must be given a prominent place in the general crop-rotation system. Inter-tilled crops, also, are often the money-making crops of the farm, and are necessary in every rotation plan, in order that the land may be cleared of weeds. Especially is this true in localities where small grains form the main crop, for by continuous grain-growing, the land becomes foul and weedy. Cultivation conserves the soil moisture and develops the fertility of the soil. It increases the supply of available plant-food by producing those conditions which favor chemical change, the growth of soil bacteria, and the decay of vegetable matter. In a sense, "tillage is manure."

Grasses and legumes maintain the supply of soil nitrogen and restore the proper soil texture. Besides, they are profitable crops, and are absolutely necessary on every farm upon which live stock is kept. Every farm must have its pasture. The pasture should be made a part of the regular crop rotation. Many soils become too light and mellow by continuous cropping and need the trampling of stock to restore their firmness. Much more grass can be produced when pastures are kept fresh and new, and the consequent increase in fertility and improvement of soil texture result in larger crops of corn, or grain, when the meadow is again under cultivation.

If manure is applied for about a year before the meadow is broken, it will stimulate the growth of grass, causing a greater production of hay, or furnishing better grazing, while the soil is being enriched by an increased root-growth which results in a larger supply of humus. Soils in which organic matter and humus are deficient may be improved in fertility and in texture by green-manuring. A cheap and practical method of green-manuring is to plant a crop adapted to this purpose in the grain stubble immediately after harvest, as suggested in the general plan for crop rotation.

It is necessary in carrying out permanent systems of crop rotation to have fields of nearly equal area, in order to grow about the same acreage of the several crops each year. In this way it is possible to keep a definite amount of live stock and to have regularity and uniformity in farming from year to year.

A practical system of crop rotation for a farm of 160 acres, divided into eight equal fields, is as follows:

ROTATION NO. 1

The Farm Plan. Showing Crops on All Fields for One Year.

Legumes and forage.	Wheat.
Wheat.	Wheat.
Wheat plus legumes.	Pasture (manured).
Spring grains (seed to grass).	Clover and grasses.

Rotation Plan, or Order of Crops on Each Field.

1st year-Grass and clover.
2nd year—Pasture (manured).
3rd year—Wheat.
4th year—Wheat.
5th year—Legumes and forage.
6th year—Wheat.
7th year—Wheat plus legumes.
8th year—Spring grains (seed to grass).

It will be observed that the crops growing on the eight fields each year are the same as those named in the order of crops on each field in eight years. By following this plan of rotation, the farmer will raise each year eighty acres of wheat; forty acres of grass, twenty acres of which may be used for pasture; twenty acres of small grains other than wheat; and twenty acres of forage crops, a part, at least, of which consists of annual legume crops. Each year twenty acres of grass land is given a dressing of manure; and a twenty-acre field of wheat is renewed in fertility by a crop of cow-peas, or by some other green-manuring crop. In the course of eight years the whole farm will have been seeded to grass and clover, and each field will have remained in grass for two years.

ROTATION NO. 2

If this system of rotation does not leave the land in grass and clover long enough, a sixteen-year rotation may be preferred.

The Farm Plan, Showing Crops on All Fields for One Year.

Forage crops.	Wheat.
Small grains plus legumes.	Wheat.
Corn.	Pasture (manured).
Small grains (seed to grass).	Clover and grasses.

Rotation Plan, or Order of Crops on Each Field.

1st year—Grass and clover.
2nd year—Grass and clover.
3rd year—Pasture (manured).
4th year—Pasture.
5th year—Wheat.
6th year—Wheat.
7th year—Wheat.
8th year—Wheat plus legumes.
9th year—Forage crops.
10th year—Corn.
11th year—Small grains.
12th year—Small grains plus legumes.
13th year—Forage crops.
14th year—Corn.
15th year—Small grains plus legumes.
16th year—Small grains (seed to grass).

By following this system of rotation, the 160-acre farm will raise each year forty acres of wheat, forty acres of small grains, twenty acres of corn, twenty acres of forage crops, twenty acres of grass for meadow, and twenty acres of grass for pasture. If corn is preferred, it may be grown in place of wheat. By this sixteen-year rotation, there are always two fields planted to grass, each for a period of four years. This requires that one field be seeded to grass every two years, and that one grass-field be plowed up every two years and planted again to wheat, or to other crops. Thus it requires sixteen years for the whole farm to receive a rotation of grass and clover.

ROTATION NO. 3

On a farm which has permanent pasture, it is not so necessary to use grasses in rotation, for the same results are secured by the use of clover and alfalfa. Clover is necessarily used in short rotations, since it produces profitable crops but two years in succession. Alfalfa, however, may be used in longer rotations. Probably four years is as long as alfalfa may be used profitably as a fertilizer. The following is a sixteen-year rotation with alfalfa, adapted to a farm with four fields of about equal area:

A Sixteen-Year Rotation with Alfalfa, Small Grains, and Corn on Four Fields.

Year.	Field A.	Field B.	Field C.	Field D.
1910[1]	Small grain (S)	Corn	Corn (M)	Corn
1911	Alfalfa (M)	Small grain (CC)	Corn	Corn
1912	Alfalfa	Corn (M)	Small grain (CC)	Corn
1913	Alfalfa	Corn	Corn (M)	Small grain (CC)
1914	Alfalfa (B)	Small grain (S)	Corn	Corn (M)
1915	Corn	Alfalfa (M)	Small grain (CC)	Corn
1916	Corn	Alfalfa	Corn (M)	Small grain (CC)
1917	Small grain (CC)	Alfalfa	Corn	Corn (M)
1918	Corn (M)	Alfalfa (B)	Small grain (S)	Corn
1919	Corn	Corn	Alfalfa (M)	Small grain (CC)
1920	Small grain (CC)	Corn	Alfalfa	Corn (M)
1921	Corn (M)	Small grain (CC)	Alfalfa	Corn
1922	Corn	Corn (M)	Alfalfa (B)	Small grain (S)
1923	Small grain (CC)	Corn	Corn	Alfalfa (M)
1924	Corn (M)	Small grain (CC)	Corn	Alfalfa
1925	Corn	Corn (M)	Small grain (CC)	Alfalfa
1926	Small grain (S)	Corn	Corn (M)	Alfalfa (B)
1927[2]	Alfalfa (M)	Small grain (CC)	Corn	Corn

[1] It is assumed that this farm has been cropped largely with corn and small grains and has received little rotation of crops. No alfalfa is growing on the farm in 1910, when field "A" is seeded. The rotation really begins in 1911.

[2] Observe that this is a repetition of 1911 crops: viz., this rotation is repeated every sixteen years, each of the four fields having received a rotation of four years in alfalfa.

(S)—Seed to alfalfa in fall. (B)—Break alfalfa sod. (This should properly be done in the spring when the new catch of alfalfa by fall seeding is assured.) (CC)—Catch crop or green-manuring crop, planted in the stubble after the small grain is harvested. (M)—A dressing of barnyard manure applied in the fall and winter as a surface dressing on the alfalfa field or spread on corn stubble land and plowed under previous to planting the following crop of corn.

This plan of rotation is really a three-year rotation on three fields, one of the four fields being kept in alfalfa as shown in the plan. The order of the rotation on each field is corn, followed by corn, followed by small grain; thus, two fields of corn, one of small grain, and one of alfalfa, are grown on the farm each year. At the end of four years, the field of alfalfa, which has not been included in the three-year rotation, is plowed and planted to corn the succeeding season. One of the three fields which has been in the regular rotation is seeded to alfalfa and comes out of the regular three-year rotation plan, remaining in alfalfa for four years. Then this field is plowed and planted to corn and becomes one of the fields in the three-year rotation series, while another field which has been seeded to alfalfa comes out of the regular three-year rotation.

It will be observed that such a plan may be followed with five, six, or more fields. With four fields, by the method described, one fourth of the farm is kept continually in alfalfa, the alfalfa fields changing every four years. This requires sixteen years for all the fields to be rotated with alfalfa. With five fields, one fifth of the farm will be in alfalfa each year, and it would require twenty-five years for the rotation to be carried out on all the fields.

ROTATION NO. 4

The Farm Plan Showing Crops on all Fields for One Year.

Clover.	Corn and legumes.
Clover	Small grains.
Corn.	Wheat (seed to grass).

Rotation Plan or Order of Crops on Each Field.

1st year—Clover.
2nd year—Clover.
3rd year—Corn.
4th year—Corn and legumes.
5th year—Small grain.
6th year—Wheat (seed to grass).

The above is a six-year rotation with clover, adapted to a farm with six fields.

Rotation No. 5 is well adapted to a farm which carries a large amount of live stock where pasture as well as alfalfa is required in rotation with small grain and corn. This is a sixteen-year rotation plan adapted to a farm with eight fields. It will be observed that four fields, or one half of the farm, is always in alfalfa or in grass, but occasionally there may be only one field in alfalfa and three in grass, or vice versa (see plan). This is the result of the arrangement by which the seeding and the breaking of grass and alfalfa sod is made to come on alternate years in order to distribute the work evenly from year to year. The plan could readily be changed so that the crops would be regular, with two fields of alfalfa and two fields of grass each year, but this would require breaking two fields every other year, one of alfalfa and one of grass. This farm would always have two fields of corn and two fields of small grain. If it were preferable, corn or some other crop instead of small grain might be grown on one of these fields each year previous to the year in which the land is seeded to grass or alfalfa.

If this plan of rotation is successfully carried out, each of the eight fields in the farm will have been in alfalfa four years and in grass four years at the end of sixteen years of cropping. During this period the whole farm will have been manured twice. Meanwhile, four fields will have produced each year crops of corn and grain, and there is little question but that a farm thus managed and properly stocked may be even more fertile at the end of sixteen years than it was at the beginning. It is the judgment of the writer that a farm upon which crops are thus carefully rotated will produce more bushels of grain in a series of years at a less cost per bushel than may be secured if practically all of the land on the farm is kept continually in grain crops. The alfalfa, grass, and other soil-maintaining crops on the farm will yield an additional income. With the live stock which may be produced on the farm,

ROTATION NO. 5

A Rotation on Eight Fields with Alfalfa, Grass, Corn, and Small Grain.

YEARS.	Field 1.	Field 2.	Field 3.	Field 4.	Field 5.	Field 6.	Field 7.	Field 8.
1910	Small grain (SA)	Corn (M)	Corn	Corn	Small grain (SG)	Corn (M)	Corn	Corn.
1911	Alfalfa	Small grain	Corn	Corn	Grass meadow	Small grain (SG)	Corn (M)	Corn (M).
1912	Alfalfa	Small grain (SA)	Corn (M)	Corn (M)	Grass meadow (M)	Grass meadow	Small grain	Corn.
1913	Alfalfa (M)	Alfalfa	Small grains	Corn	Meadow or pasture (B)	Grass meadow	Small grain (SG)	
1914	Alfalfa (B)	Alfalfa	Small grain (SA)	Corn (M)	Corn	Meadow or pasture (M)	Grass meadow	Small grain.
1915	Corn	Alfalfa (M)	Alfalfa	Small grain	Corn (M)	Meadow or pasture (B)	Grass meadow	Small grain.
1916	Corn (M)	Alfalfa (B)	Alfalfa	Small grain (SA)	Small gran	Corn	Meadow or pasture (M)	Grass meadow.
1917	Small grain	Corn	Alfalfa (M)	Alfalfa	Small grain (SA)	Corn (M)	Meadow or pasture (B)	Grass meadow.
1918	Small grain (SG)	Corn (M)	Alfalfa (B)	Alfalfa	Alfalfa	Small grain	Corn	Meadow or pasture (M)
1919	Grass meadow	Small grain	Corn	Alfalfa (M)	Alfalfa	Small grain (SA)	Corn (M)	Meadow or pasture (B)
1920	Grass meadow	Small grain (SG)	Corn (M)	Alfalfa (B)	Alfalfa (M)	Alfalfa	Small grain	Corn.
1921	Meadow or pasture (M)	Grass meadow	Small grain	Corn	Alfalfa (B)	Alfalfa	Small grain (SA)	Corn (M).
1922	Meadow or pasture (B)	Grass meadow	Small grain (SG)	Corn (M)	Corn	Alfalfa (M)	Alfalfa	Small grain.
1923	Corn	Meadow or pasture (M)	Grass meadow	Small grain	Corn (M)	Alfalfa (B)	Alfalfa	Small grain (SA)
1924	Corn (M)	Meadow or pasture (B)	Grass meadow	Small grain (SG)	Small grain	Corn	Alfalfa (M)	Alfalfa.
1925	Small grain	Corn	Meadow or pasture (M)	Grass meadow	Small grain (SG)	Corn (M)	Alfalfa (B)	Alfalfa.
1926	Small grain (SA)	Corn (M)	Meadow or pasture (B)	Grass meadow	Meadow grass	Small grain	Corn	Alfalfa (M).
1927	Alfalfa	Small grain	Corn	Meadow or pasture (M)	Grass meadow	Small grain (SG)	Corn (M)	Alfalfa (B).
1928	Alfalfa	Small grain S(SA)	Corn (M)	Meadow or pasture (B)	Meadow or pasture (M)	Grass meadow	Small grain	Corn.

(M)—Manured. (B)—Break sod either in fall or spring. (SA)—Seed to alfalfa; this may be done in the fall and a catch of alfalfa secured without losing a crop. (SG)—Seed to grass, which may also be done in the fall in the West and South, and in the spring with grain, in the Central and Eastern states.

an additional profit may accrue to the farming business. Meanwhile, by such a system of farming, the soil of this farm may become more fertile and more capable of producing large crops of corn and grain; while by the continuous cropping system, it would become largely depleted in fertility.

Improvement of Grasses

Up to the present time very little has been done in the way of breeding or of improving grasses. The native grasses of the West thrive there by Nature's breeding and selection and not by the hand of man. The testing of varieties of grasses to determine their adaptation to soil and to climatic conditions is the first step toward the improvement of the grasses in any locality. The improvement work with other crops, such as wheat and corn, has shown that even the varieties which are hardiest and best adapted to a given soil and climate, may be still further improved in yield and in hardiness by a method of selection and testing which discovers the superior individuals which may be made the foundation stock for new strains or improved varieties. This work has been just begun with the cereal grains, but with remarkable results, and there is no reason why similar improvement may not be made with grasses by similar methods of selection and breeding.

Each kind of grass as ordinarily sown by the farmer consists in reality of a number of more or less distinct varieties mixed together. With the usual methods of securing grass-seed, there is no opportunity to separate these varieties; but if the seed from different heads or from different plants is planted in separate rows or plots, then pure and superior strains may be propagated. In fact, enough work along this line has already been accomplished to show valuable results. Dr. A. D. Hopkins, at the West Virginia Experiment Station, has produced a number of different varietal types of timothy by this method of head-row breeding. In a similar manner, Professor Leckenby, of the Eastern Oregon Experiment Station, has isolated twenty-two different varieties of *Bromus inermis* as distinct in their agricultural characteristics as are the ordinary varieties of wheat. At the Kansas Station, work of this character is being undertaken with *Bromus inermis* and timothy. It is probable that each of the valuable standard grasses may be separated into varieties, some of which will show a marked improvement over the ordinary mixture of varietal types.

This breeding work requires technical knowledge and much time and patience in order to establish the new strains and varietal types. The work really belongs to the specialist and to the experiment stations, but the farmer may assist greatly in an important phase of the grass-improvement work by bringing under cultivation some of the more valuable wild grasses. If farmers in different portions of the State would persistently gather the seed, and plant and cultivate these wild grasses, the result would shortly be the development of improved domesticated varieties. The mere growing of these wild plants under more favorable cultural conditions should cause a general improvement of the grass and may develop individual plants, which, if observed, separated, and propagated, might become the founders of a new and better variety.

Characteristics of Some Important Grasses

In this discussion of several important grasses, mention will be made mainly of the special characteristics, culture, and uses of the grasses discussed.

Timothy

Timothy (*Phleum pratense*), also called Herd's Grass, is a native of America, indigenous to the New England states. It is said to have been discovered and brought to notice in the middle of the eighteenth century by one Timothy Herd, of New Hampshire; hence, the name. It is a perennial grass which grows in stools, or tillers, and does not spread from the root, but readily thickens by re-seeding under favorable conditions, forming a nearly perfect sod. The stems are upright with few leaves and, unless thickly sown, the grass forms coarse, stemmy hay. It grows to a height of from two to four feet, according to conditions, and is surmounted by a spike two to ten inches long. When in full bloom a field of timothy is an attractive sight.

The root-growth of timothy is both bulbous and fibrous. The fibrous character is relatively greater in moist, sandy soils. As shown in the sample (see Fig. 8), the roots may reach to a depth of several feet, though the grass is generally considered a surface feeder. (Perhaps this grass roots more deeply in Kansas soil—see Fig. 18.)

ADAPTATION AND USES

Timothy easily ranks first as the great standard hay-grass of America. Its general use and extensive cultivation arises in part from the wide range of its adaptation, but more from its many good qualities. It is easily grown, cured, and transported; it seeds abundantly, and the seed is easily saved. Timothy hay has an attractive appearance and is highly palatable and very nutritious. It has been found to be especially adapted to the needs of horses. For cattle and sheep, a combination of timothy and clover is preferable to timothy alone.

Timothy requires a temperate climate and a moist, fertile soil. It is well suited to river-bottom lands rich in humus, and thrives well in prairie loam and even in stiff clay soils which are well watered. Dry, sandy soils and soils low in fertility are poorly adapted to the growing of timothy. Timothy succeeds well in eastern and southeastern Kansas, and in portions of central and south-central Kansas it may be recommended under favorable conditions. While timothy is essentially a hay grass, it may be used for pasture. It is easily injured by the trampling of cattle and by close grazing, and hence is not considered one of the best pasture grasses. However, for pasture, it is often advisable to seed it in combination of other grasses and clover.

SEEDING AND RENEWING

Timothy is preferably sown with clover for meadow, the Alsike, mammoth clover or medium red clover being preferred according to soil conditions, to the use which is to be made of the hay, and to the preference of the grower. Alsike clover and timothy should be preferred on wet land; also, to produce a fine quality of hay for feeding sheep or young stock. Mammoth clover and timothy mature at about the same time and are well suited for growing together where each thrives well, but the combination makes a rather coarse, unpalatable hay. Medium red clover is more often seeded with timothy than are the other clovers. This combination makes an excellent crop even though the medium red clover does mature a little earlier than the timothy. The writer would usually recommend to seed medium red clover with timothy in central and in southern Kansas, since, in a favorable season, timothy may make two cuttings the same as medium red clover. A good second cutting from Alsike or from mammoth clover is seldom secured.

Timothy may be sown either early in the spring or early in the fall. Prefer to seed clover and timothy in the spring and do not seed with a nurse-crop in the fall. If the grass is sown alone in August or in early September and starts well, it should produce a fair crop of hay the following season.

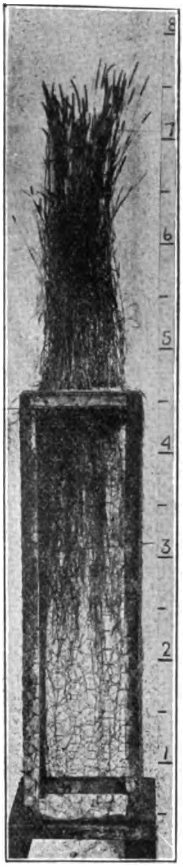

Fig. 17.—Timothy roots. Sample taken July 2, 1909, six years after seeding.

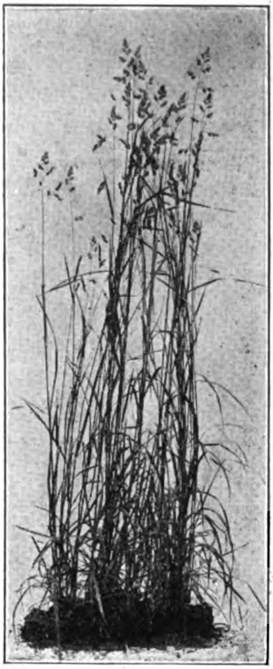

Fig. 18.—Orchard-grass.

A field of timothy may be maintained for ten years or more and return profitable yields by growing it with clover or by manuring and fertilizing the field. If the grass becomes thin or weedy, add at intervals, preferably early in the spring, a little seed both of timothy and of clover. Usually, enough seed of both clover and timothy will shell out to maintain the stand, especially if an occasional crop is harvested for seed. Timothy does not form a very tough sod. The sod may be broken readily either in late summer or in early spring and the land planted with wheat, corn, or other grain-crops. Care should be taken to disc and to harrow the sod well in order to put it in a well-pulverized condition before planting.

Orchard-Grass

Orchard-grass (*Dactylis glomerata*) is a native of Europe, but has become very widely distributed and is now grown throughout the countries of Europe, Western Asia, Northern Africa, and in many parts of North America. It is successfully grown in the eastern half of this State, but is not adapted to dry-land conditions. It is a hardy perennial grass, but not so good a cold or drought resister as *Bromus inermis*, though it is grown successfully farther south. Orchard-grass is essentially a moist-climate grass, but it will stand more drought than will meadow fescue or Kentucky blue-grass.

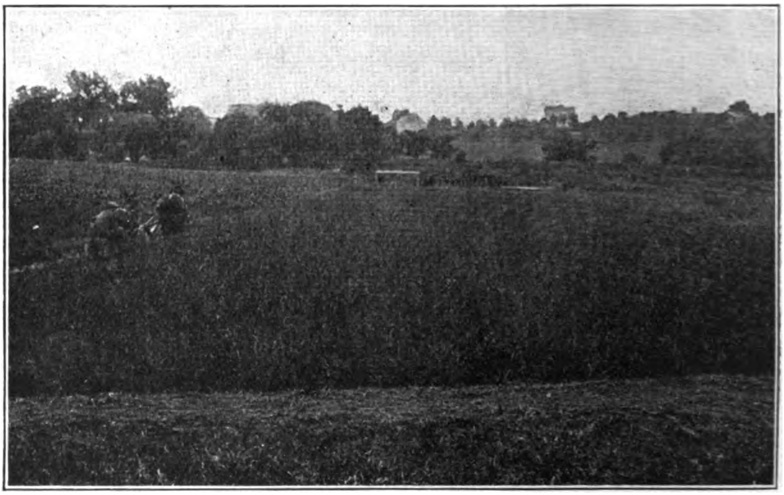

FIG. 19.—Cutting the Orchard-grass for hay, June 15, 1909. This plot was seeded in the spring of 1906.

Next to brome-grass, it is one of the earliest grasses to start in the spring and grows very rapidly. It reaches maturity in May or in early June, even earlier than Kentucky blue-grass. Its habit is to grow in bunches or tufts unless sown thickly. However, this grass will soon thicken up in a pasture by self-seeding. In the course of three or four years, it will form a dense growth and a very thick sod. If allowed to seed occasionally, it will even thicken up in a meadow in the same way. Due to its self-seeding habit, orchard-grass is a more nearly permanent grass than is meadow fescue, and it often continues to improve in stand and in productiveness for several years after seeding. It is a very hardy grass under favorable conditions; meadows have been reported as producing good crops for a dozen years.

Orchard-grass is particularly well adapted to grow in the shade, and is often grown in orchards. It is an excellent pasture grass when rightly managed. It ranks high in nutritive value, but is not relished by live stock so well as Kentucky blue-grass or *Bromus inermis.* It grows large stems very quickly and becomes tough and unpalatable, hence requires mowing to start a new growth. It makes good hay when cut early, but, owing to the quickness with which it matures, it is apt to become too mature before cutting, when it makes a coarse, bulky, and unpalatable hay. For these reasons it has never become very popular as a hay grass.

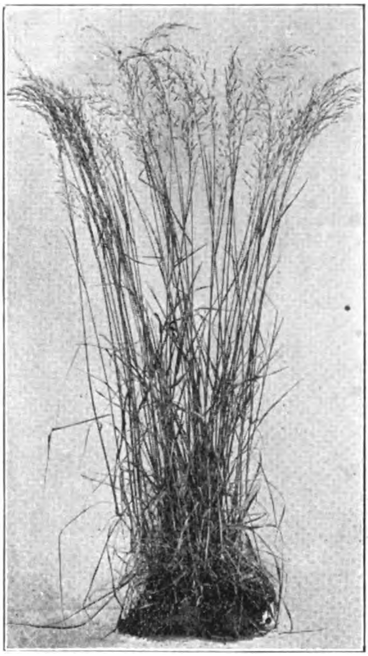

Fig. 20.—Meadow Fescue.

Meadow Fescue

Meadow fescue (*Festuca pratensis*), usually known as "English blue-grass"[1] in Kansas, is indigenous to Europe and Western Asia. It is much grown in Great Britain and in Northern Europe, and is a hardy perennial grass, well adapted to endure low temperatures. It may also endure warm climates, as shown by its successful culture in the South, where it is especially valuable for winter pasture. It is a moisture-loving grass and is not well adapted to dry climates.

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[1] There is no good reason for this name, other than that the grass is grown largely in England for pasture and for meadow. It seems desirable, therefore, to call the grass by its proper name, "meadow fescue."

Meadow fescue is grown successfully in the area south of the Kansas river and extending west from the Missouri line about one hundred miles. It thrives best on the fertile and heavier soils, although it is grown largely on the slopes and uplands. In eastern Kansas it will grow well on any good corn land.

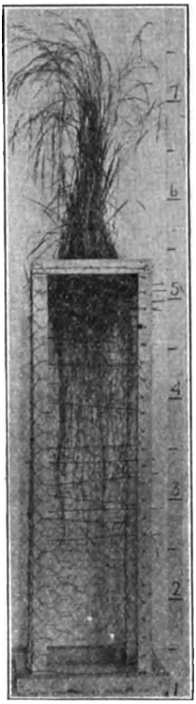

FIG. 21.—Meadow Fescue roots. Sample taken June 24, 1909, three years after seeding.

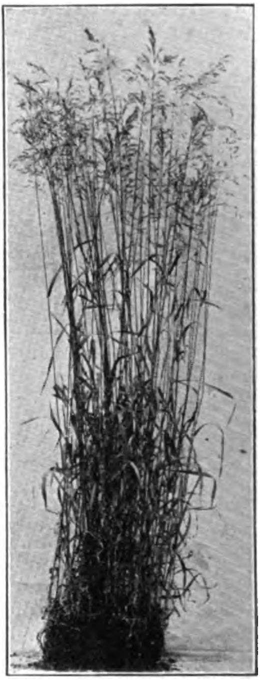

FIG. 23.—*Bromus inermis.*

Meadow fescue is a tufted grass more spreading in habit than orchard-grass, but not so rank nor so rapid a grower. It obtains its best development the second or third year after seeding. In some of its features it resembles the Kentucky blue-grass. The leaves have a bluish tint and the stems are rather stiff and wiry, but the panicle of the head is narrower and less open than that of the Kentucky blue-grass. Meadow fescue blooms later than the blue-grass, but the blades start early in the spring. The quantity of forage is not great, but the grass is rich in nutrients and well liked by stock both as pasture and as hay. The hay, unless cut early, is apt to be a little tough or woody. This grass usually produces stems only once in a season, but produces a great aftermath of foliage in favorable seasons, which remains green late into the fall and winter, furnishing excellent pasture.

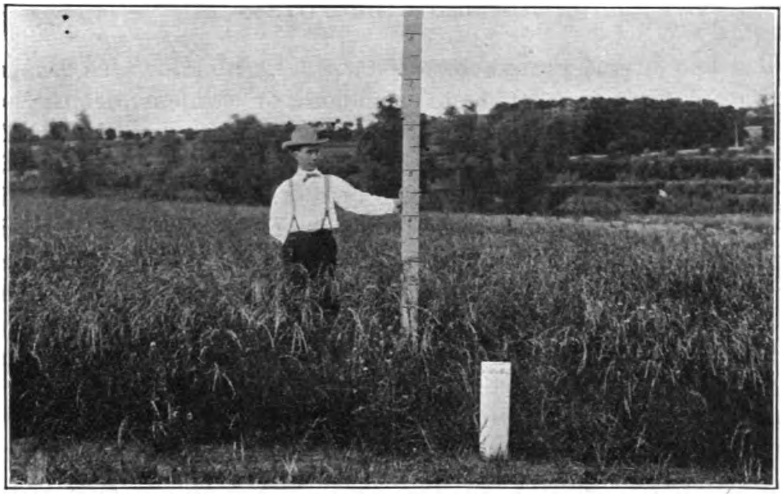

FIG. 22.—Variety plot of Meadow Fescue, June, 1904, just before cutting for hay. Grass was seeded in the spring of 1903.

In Kansas the grass is grown especially for its seed, Kansas supplying about seventy-five per cent. of the total amount of seed produced in the United States. Johnson county, Kansas, leads in the production of meadow fescue seed. This seed finds a ready sale in European countries, where it is sown for meadow and for pasture. The price is regulated by the supply and the foreign demand, and has ranged from two to ten cents per pound. The largest seed crop produced in Kansas was harvested in 1896 and was estimated at 3,360,000 pounds. The yield of seed for the first three or four years after planting averages from six to twelve bushels per acre (twenty-four pounds per bushel), although yields of from fifteen to twenty bushels have been reported. In from three to five years the grass makes a less vigorous growth and the yield of seed decreases. The practice is to plow the sod at the end of the fourth year and to rotate with corn or other crops for a few years before the field is again seeded to grass.

The fact that meadow fescue has proven to be a profitable crop when grown for seed, has perhaps caused it to be valued more highly for pasture and as a hay grass than it really deserves. It appears that meadow fescue is not so extensively adapted to conditions in this State as are orchard-grass and *Bromus inermis.* It is less permanent, and less valuable for pasture, than either of these grasses, while timothy exceeds it as a hay grass in that section of the State where meadow fescue grows best.

Russian Brome-Grass

Russian brome-grass (*Bromus inermis*), also known as Australian, or Hungarian, brome and as smooth, or awnless, brome, is a native of Asia and of Europe, where it has been cultivated for more than a century. Introduced into the United States in the early eighties, it has become widely distributed throughout the northern and western part of our country, thriving well in the northern states and succeeding well in the West under dry-farming conditions. It is a very hardy grass, resisting both cold and drought, but it will grow well and produce good crops only in fertile soil and with a moderate supply of moisture. It does not succeed well in a hot climate, central Kansas being about the southern limit for the profitable growing of *Bromus.*

Bromus inermis is a perennial grass spreading by underground root-stems which produce numerous shoots and a very dense fibrous growth of roots that often fill the soil completely to a depth of five or six feet. It thickens very rapidly, even though the stand may be thin at first, and soon forms a very tough, thick sod. The stems are numerous, reaching a height of from three to four feet under favorable conditions, but often the growth in height is much less. The leaves are numerous and large, furnishing a dense mass of foliage which completely covers and shades the ground. These large leaves add greatly to its value for hay and for pasture. The fully developed head is a spreading, open panicle averaging from four to six inches in length, though the head may be longer or entirely wanting when the grass is old and very thick. Brome-grass makes good hay, but it is essentially a pasture grass. Live stock of all kinds are fond of it and, under favorable conditions, it will furnish continuous grazing from early spring until late in the autumn. In this respect, when *Bromus inermis* is in its prime, it exceeds all other grasses. Its fault is that it thickens rapidly, becoming sod-bound to such an extent that its growth is checked in from three to five years.

As a hay grass *Bromus* is equal to timothy in feeding value, but timothy exceeds it in commercial value. Also, timothy exceeds it in yield and in permanency in localities to which the two grasses are equally well adapted. *Bromus* exceeds timothy in hardiness and in drought resistance, and it may be grown successfully on the Western Plains where the annual rainfall does not exceed twelve to fifteen inches. Under such conditions, however, it is much less productive. It lives under dry conditions that would destroy many other grasses, and when the rains come it will start again vigorously. Its great drought resistance is doubtless due in part to its extensive and deep root-growth. (See Fig. 25)

Compared with other important grasses, *Bromus inermis* succeeds well on the lighter, sandier soils and drier lands; but, like other grasses, it grows better on deep, rich, fertile loam well supplied with moisture. The grass may be sown either early in the fall or early in the spring, preferably with alfalfa or with clover. It is somewhat difficult to sow on account of the large size and light weight of the seed. It is usual to sow *Bromus inermis* broadcast, by hand, since the seed is very light and is sown with difficulty with the drill or grass seeder. Certain of the wheelbarrow seeders, however, have a special box attachment for seeding *Bromus inermis.* It is possible also to sow *Bromus inermis* with a common grain drill. To do this it is necessary to place a shaker in the bottom of the seed box. The shaker is made in this manner: Nail together two narrow strips of inch board in the bottom of the seed box, splicing them in the center; drive two tenpenny nails through this board into each seed cup; attach to the middle of the board a handle which reaches to the top of the box. Put only a small amount of seed into the box at one time. With a boy working this handle to prevent the seed from clogging the drill, it is possible to do a fairly even job of seeding.

Another method of seeding is to mix the *Bromus inermis* seed with oats so as to sow about one bushel of oats per acre with the required amount of *Bromus inermis* seed. On light soils which are inclined to drift with the wind, oats serves to protect the soil from the force of the wind. The oats should be cut early for hay in order that the young grass plants may not be destroyed by drought or by shading. The method of drilling in the seed is often perferred in light soil and in a dry climate. As a rule, the seed should not be covered over one half of an inch to one inch deep. If the ground is dry when the seed is sown, rolling may be beneficial, but the harrow should follow the roller.

It is very important to test *Bromus inermis* seed and to be sure that it will germinate. Much impure and poor *Bromus inermis* seed has been sown. With good seed and under reasonably favorable conditions, *Bromus inermis* is not an especially hard grass to start. When once established, it is very hardy and, as stated, it tends to become thicker from year to year.

Bromus inermis should not be considered as a permanent pasture grass or as meadow grass. It is rather a grass to be used in rotation with other crops. It is usually preferable to re-seed new fields every three or four years, plowing the old fields and planting them to corn or to other crops. It is possible to renew the growth of *Bromus inermis* after it has become old and sod-bound by partially breaking the sod and by discing thoroughly to level the field. The writer has tried this method and has also tried very thorough discing of the sod, with fairly favorable results.

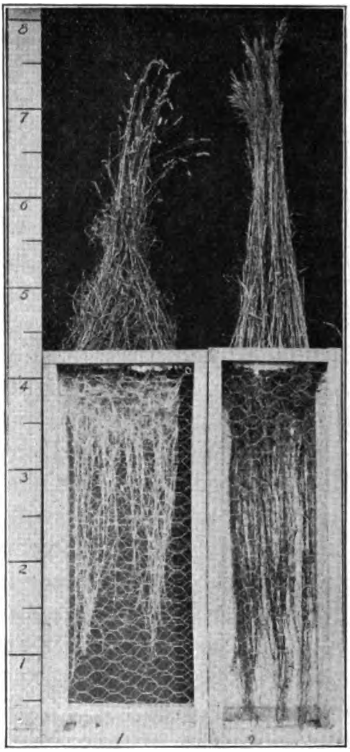

FIG. 24.—*Bromus inermis* roots on the right. Sample taken June 30, 1903, showing root development three years after seeding. Orchard-grass roots on the left. Sample taken June 27, 1903, showing development of roots from one plant or stool two or three years after seeding.

The grass was renewed in growth within a year or two, and produced fairly good yields again; but the renewing in this way took a longer time and proved to be more expensive than the new seeding of another field. Hence it is usually more desirable to seed other land rather than to attempt to renew an old meadow or pasture of *Bromus inermis*.

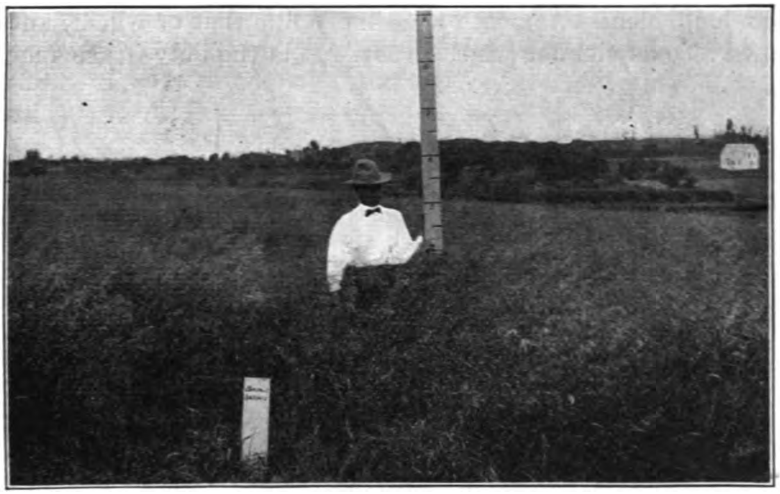

FIG. 25.—Variety plot of *Bromus inermis* June 23, 1904, just before the crop was cut for hay. Seeded in the spring of 1903.

Brome-grass is very persistent and somewhat difficult to destroy when it is once well established, but farmers need not fear it on this account since, by proper methods, it may be readily and fully eradicated. Prefer to break Brome-grass sod late in the summer or early in the fall. Plant this field with an inter-tilled crop the succeeding year. Give the new crop thorough cultivation. This method used at the Kansas Experiment Station has practically eradicated the grass in a single season.

Western Rye-Grass

Western rye-grass (*Agropyron tenerum*) is a native American grass, the famous bunch-grass of the bunch-grass ranges of the Canadian northwest. It is one of the hardiest perennial grasses, and, according to Professor Shaw, none of the cultivated grasses excel it for growing under dry conditions, and no amount of cold seems to injure this grass. It is superior to *Bromus inermis* in this respect, but it is not well adapted to a hot climate, and does not thrive so well in western Kansas as it does in the states farther north. This grass was first grown under cultivation and brought to public notice in the early eighties by Kenneth McIvor, Verben, Manitoba, Canada. It has been rapidly introduced as a cultivated grass throughout the northwest, and is considered one of the most valuable hay and pasture grasses in the drier, colder sections of the United States and Canada.

Western rye-grass resembles somewhat the rye plant, but it has a long, slender, smooth head more like that of wheat, and is known also as slender wheat-grass. It is the only grass among hundreds of species or varieties growing wild on the prairies of the West and Northwest which has as yet been domesticated. On the range, it grows in height from twelve to eighteen inches; but under cultivation, with favorable conditions, its height may reach three or four feet. Each stool, or tiller, produces many leaves and several stems. These grow erect and bear heads six inches or more in length. No study has been made of the roots of this grass at this Station, but the roots are fibrous in character, abundant, and extend deep into the soil.

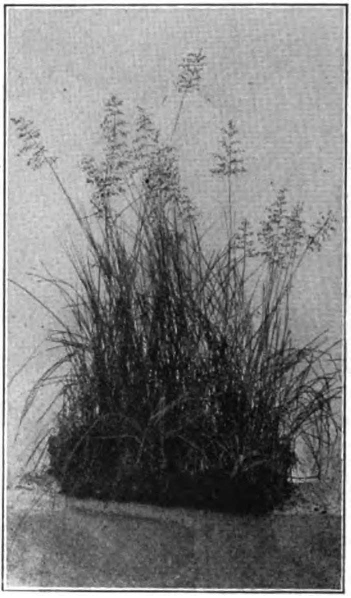

FIG. 26.—Kentucky Blue-grass.

Western rye-grass starts rather slowly in the spring and ceases growth early in the autumn, but it is a good late spring and summer grass for pasture. This grass makes good hay and outyields

Bromus inermis where the two are equally well adapted. The hay is easily handled, and it is readily eaten by stock if cut before it has become too mature. It is a great producer of seed, and the seed is easily sown. Western rye-grass may have considerable value in western Kansas in re-setting the older tilled lands with grass to prevent soil-drifting and to restore the soil humus. It is doubtful, however, whether the grass is so hardy or so well adapted for growing in western Kansas as are the native prairie grasses, such as the buffalo-grass and bluestem. Other rye-grasses, such as perennial rye-grass (*Solium Perenne*) and Italian rye-grass (*Solium Italicum*), have little value in this State.

Kentucky Blue-Grass

Kentucky blue-grass (*Poa pratensis*), with two or three of its allied varieties, is the greatest American pasture grass, and it is grown extensively throughout a large part of the United States and Canada. Professor Shaw states that it is grown more or less in every state in the Union. From the Mississippi to the Atlantic it occupies more territory and has been found more useful for grazing than any other grass. It is also considered a valuable pasture grass for a considerable distance west of the Mississippi river. In the western part of the Great Plains region, conditions are too dry for the successful growing of Kentucky blue-grass except by irrigation.

Fifty years ago there was little or no Kentucky blue-grass in Kansas, but it has been gradually working west even without field seeding, until it is the common roadside grass of a large part of eastern Kansas, and furnishes the grazing in many of our pastures which were originally devoted to the wild prairie grasses. Kentucky blue-grass spreads by underground roots, hence it forms a perfect sod. It makes a very fibrous growth of roots near the surface, but is not a deep-rooting grass and does not stand drouth well. It starts very early in the spring and matures early, blooming in May or early in June. This grass makes little growth in the hot summer months, but with sufficient moisture it thrives again in the fall, supplying excellent grazing until freezing weather. It is one of the most palatable and most nutritious grasses for all kinds of stock, but has little value for hay. Kentucky blue-grass is not so productive as the other grasses used for hay, and the leaves form a mat so close to the ground that they can scarcely be cut with the mower. The grass is difficult to harvest so as to make a good quality of hay, as the grass matures very rapidly, the stems soon becoming tough and wiry.

Kentucky blue-grass is also the great lawn grass of America, for which use it is particularly well adapted because of its abundant growth of reclining leaves which lie very close to the ground and which make a velvety sward which admits of frequent clippings without injuring the grass, provided the lawn is well watered and well fertilized. White clover should always be associated with Kentucky blue-grass both for pasture and for lawn, in order that the grass may remain permanent and productive.

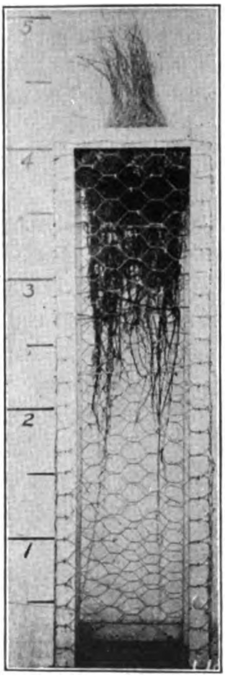

FIG. 27.—Kentucky Blue-grass roots. Sample taken September 4, 1903, from the Agricultural College campus. Age of grass not known; may be described as old Blue-grass sod.

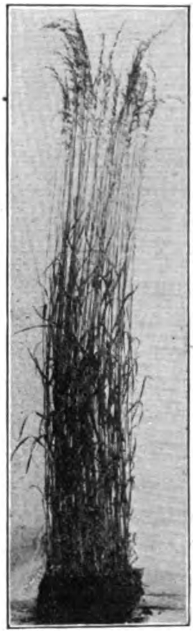

FIG. 28.—Tall Meadow Oat-grass.

Redtop

Redtop (*Agrostis vulgaris*) is the most commonly cultivated variety of the species of grasses indigenous to America, among the more common of which are redtop, Herd's grass, bent-grass, Borden's grass, dew grass, summer grass, finetop, and Rhode

Island bent-grass. Redtop is a perennial grass which grows from a few inches to three or four feet in height under varying conditions of soil and climate. The stems are erect, with slender, smooth, and rounded linear leaves. The panicle is oblong and spreading, and usually of a purple or reddish tint. The roots are more or less fibrous or creeping, hence the grass is particularly well adapted to low or wet lands. It starts later in the spring than Kentucky blue-grass, grows more slowly, and is later in maturing. It is not so valuable for pasture or for hay as timothy, being less palatable. Redtop hay is less suitable for marketing, though it is often grown with timothy for hay, and with timothy, meadow fescue, or orchard-grass and Alsike clover, for pasture. In wet lands it gradually supplants other grasses. Redtop does not have a wide adaptation or utility in Kansas, but for hardiness to thrive in poorly drained areas, the peculiar conditions for which it is suited, there is no other domesticated grass superior to it.

At this Station, on upland soil, redtop has not appeared to be as persistent as timothy, even though the grass was favored by being seeded in the lowest and best-favored portion of the field.

Tall Meadow Oat-Grass

Tall meadow oat-grass (*Arrhenatherum avenaceum*) is said to be the most valuable variety of the oat-grass family. This is a coarse, tall-growing perennial grass resembling the common oat, but more slender in every way. The grass grows in tufts, or bunches, commonly three or four feet high, but often reaching a height of five or six feet. Oat-grass does not make a sod, and should usually be sown in combination with other grasses. It is of considerable value for meadow and for pasture in Kansas and in the states farther south. Tall meadow oat-grass is even earlier in maturing than orchard-grass, being ready to cut for hay early in June. It springs up quickly after cutting, furnishing a good aftermath for pasture; or, under favorable conditions, two or three cuttings of hay in a season. In the southern states, this grass grows late in the fall and furnishes winter pasture. The grass seeds freely and the seed is strong in vitality. Oat-grass starts quickly and grows rapidly, usually yielding a hay crop from spring seeding the first season. The grass is deep rooting, resisting cold, drouth, and heat, and may be recommended for seeding in western Kansas under the more favorable soil conditions. For pasture, it is preferable to sow it in combination with western rye-grass and *Bromus inermis*.

Farmers disagree as to the feeding value of tall meadow oat-grass. Some think oat-grass is of small feeding value and others speak very highly of it. Its feeding value is probably a little below the average of standard grasses. It makes a rather coarse, unpalatable hay unless great care is taken to harvest it before it matures, and it reaches maturity very quickly after heading. Also, its rapid, coarse growth and slightly bitter taste cause stock to prefer the other grasses for grazing. The main characteristics which recommend it are its hardiness and rapid, vigorous growth.

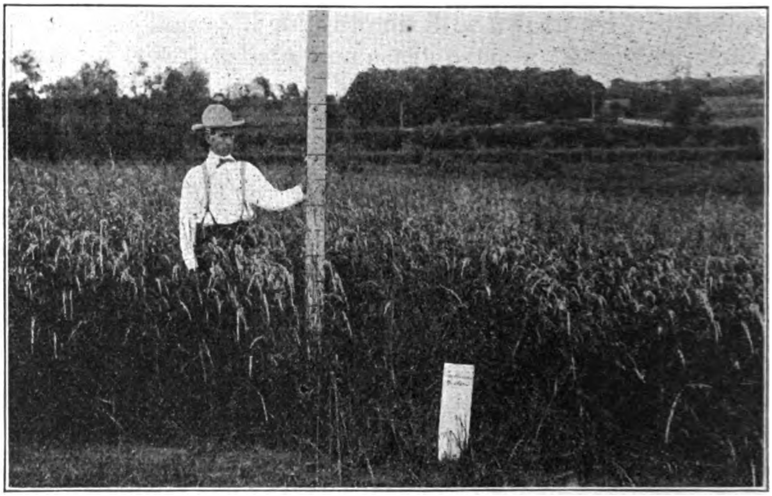

FIG. 29.—Variety plot of Tall Meadow Oat-grass. Photo taken in June, 1904, just before cutting for hay. Seeded in the spring of 1903.

Bluestem Grasses

There are two valuable species of this excellent hay and pasture grass which grow abundantly on the prairies of eastern and central Kansas. These are the big bluestem (*Andropogon furcatus*) and the little bluestem (*Andropogon scoparius*), both of which are dry-land grasses. Little bluestem resists drouth better than big bluestem and is better adapted to the higher lands. The big bluestem luxuriates in the draws and on lower lands, where the soil is deeper and the supply of moisture is greater.

These grasses form a large part of the famous prairie hay of Kansas and Nebraska. They are probably not so well adapted for pasture as for meadow, since by close pasturing they are soon destroyed. This is due to their habit of growing in bunches or stools; to their method of propagation, which is by seed only; and to the fact that they are spare seeders, which is their greatest fault. It is safe to affirm that the bluestem grasses would long since have been cultivated if an abundance of seed could have been secured. There is no question regarding their valuable qualities for meadow. Even in the wild state, their value as hay grasses on the Western Plains is not exceeded by that of any of the domesticated grasses. By scientific breeding and selection, doubtless the bluestem grasses will become still more valuable and will help to solve the problem of returning to grass the western lands which have already been cropped too long with wheat and other grain.

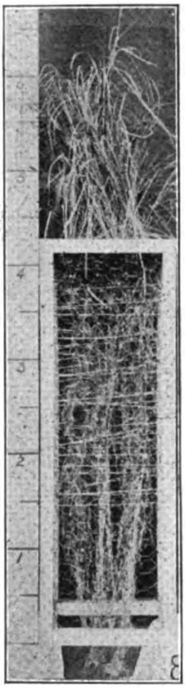

FIG. 30.—Big Bluestem (*Andropogon furcatus*) roots. Sample taken September 4, 1903, from an old prairie meadow on the Agricultural College farm. Observe the thick net work and fibrous growth of roots and the deep root system.

In Fig. 30 is shown a sample of the big bluestem grass roots. The sample was taken from the Experiment Station pasture, and represents the full growth of the grass to August 2. This is an excellent specimen of grass roots, and is indeed a wonder when we consider the large number of roots and their great length. The roots were broken off four and a half feet from the surface,

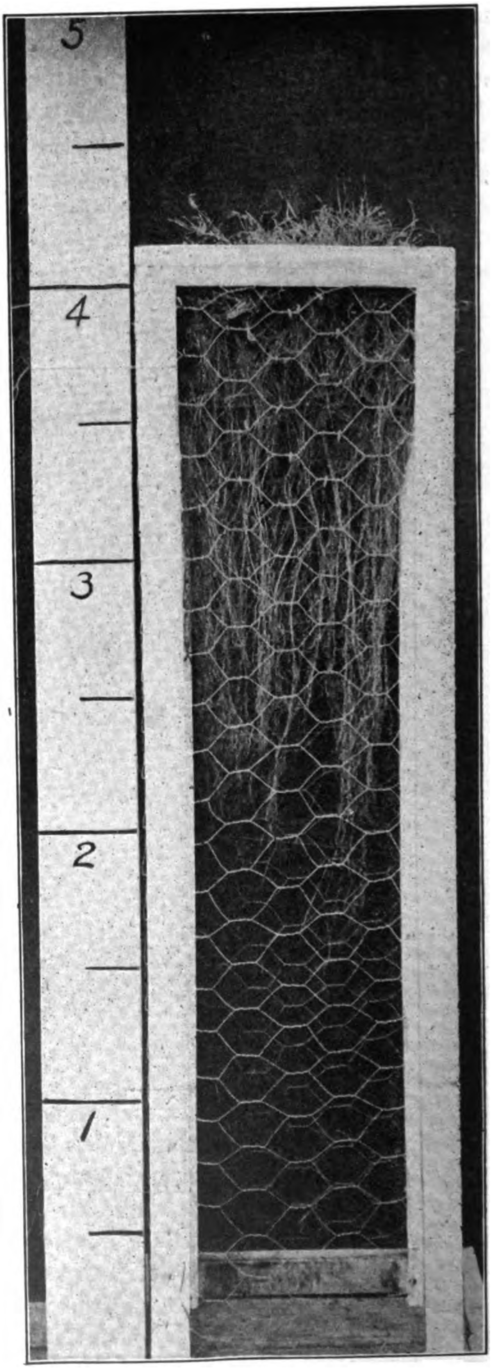

Fig. 31.—Buffalo grass roots. Sample taken October 20, 1903. from an upland prairie pasture near the Agricultural College farm.

but from their size they must have extended at least two feet deeper into the compact clay subsoil. This grass makes a deeper root growth than *Bromus inermis*, and the roots, though less numerous, are somewhat coarser, presenting a somewhat irregular and tangled growth. Big bluestem forms a dense, tough sod, from six to eight inches thick, and the subsoil is filled with a great mass of roots. After the sod is broken, the roots gradually decay, supplying nitrogen and humus to the soil.

Buffalo-Grass and Grama-Grass

No grass of the Western Plains is better known for its valuable qualities as a pasture grass than is the famous buffalo-grass (*Bulbiles dactyloides*), a sample of which is shown in Fig. 32. Withstanding drouth, hot winds, and the persistent trampling of cattle, this grass thrives on the dry uplands of central and western Kansas, filling the soil with roots and covering the earth with a thick mantle of stems and leaves. Owing to the spring rains, it makes a good, early growth. As summer advances and dry weather begins, it ceases to grow, but does not die. The crop cures on the ground, furnishing grazing of the best quality. When the rains come in the fall, the grass again starts to grow, producing a second crop which cures on the ground, and continues to furnish grazing throughout the winter. Buffalo-grass spreads by means of runners which creep along the ground and root at intervals. The leaves are short and curly, and the plants form a mellow sod, covered with two or three inches of soft, cushion-like foliage. The seed-stems extend a few inches above the foliage, but they are not very numerous. The grass has practically no value for hay, since it produces very lightly and cannot be harvested readily.

As the sample shows, the roots are numerous, but do not penetrate deep into the soil. The first four inches of soil, however, are completely filled with roots, which form a fairly firm sod. The roots are thread-like, and almost white in color. On the whole, the feeding capacity of this grass is much less than that of *Bromus inermis* or big bluestem; hence it is less productive than either of these grasses. Although it is uninjured by drouth, it ceases growth sooner when a drouth approaches than do the deeper-rooting grasses mentioned.

Bermuda Grass

Bermuda grass (*Cynodon dactylon*) is a creeping perennial grass, the stems of which produce nodes, or joints, at short intervals, and each node is capable of producing a new plant. This grass spreads very rapidly under favorable conditions, roots at each joint, and produces numerous upright leaf-branches, from four to six inches in height. These branches bear the flowers and seed in from three to six slender spikes. Each joint has from two to four leaves, which are flat, spread widely, and gradually taper to a slender tip. The grass produces shallow, under-ground root-stalks, as well as surface runners, but the roots are mainly fibrous, and deep feeders.

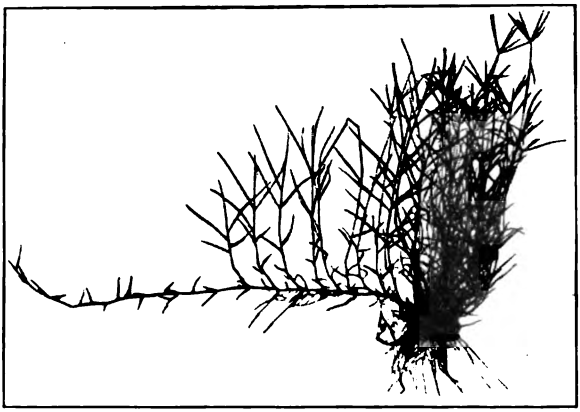

FIG. 32.—Bermuda grass. (Courtesy of the Oklahoma Experiment Station.)

Bermuda grass is the great pasture grass of the sub-tropical and warmer temperate regions throughout the world, and is probably a native of tropical Asia. It was introduced into Georgia during the War of 1812, and has been widely distributed throughout the South, where it is now considered the most valuable pasture grass, holding the place in those states that Kentucky blue-grass holds in the North. Like Kentucky blue-grass it is also the universal lawn grass in the section over which it has spread. Bermuda grass is distinctly a warm-weather grass; it will not grow in cold weather, and is not hardy where the temperature falls much below the zero point. At this Station it usually winter-kills, but in the southern counties of the State it is comparatively hardy, and farmers there have reported that they have grown it successfully for periods of from four to eight years. This grass is grown successfully throughout the larger part of Oklahoma. The

Experiment Station of that state is breeding this grass and has developed a hardier variety. The hardy Bermuda is the variety recommended for planting in northern Oklahoma and southern Kansas.

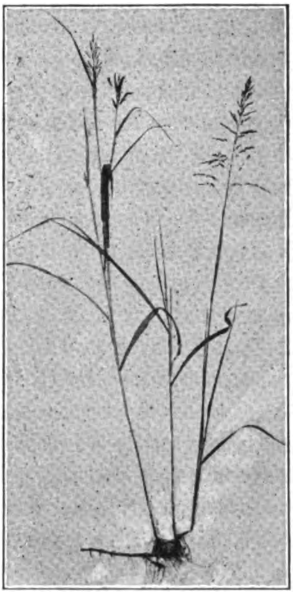

FIG 33.—Johnson grass. (Courtesy of the Tennessee Experiment Station.)

In its habits of growth, Bermuda grass is almost the reverse of Kentucky blue-grass. It starts to grow late in the spring, grows slowly at first, and thrives best in the hottest summer weather. With the earliest frosts, the grass is killed to the ground, remaining brown and dead during the winter and early spring. Like other grasses, it grows most luxuriantly in fertile soil, but it will also grow on poor, sandy, gullied, or worn soils. To these soils, Bermuda grass furnishes protection and supplies humus, but it will not yield much pasture. It is one of the best soil-binding grasses, and is very persistent, withstanding both heat and drouth ; but it does not thrive in the driest lands of western Texas and Oklahoma, and it will not grow in the shade.

Bermuda grass is primarily a pasture grass and is relished by all kinds of stock. It will stand close grazing and much trampling. It also makes hay of excellent quality, but will not grow rank enough to mow and handle well, except on very fertile soil. Under the more favorable conditions, it furnishes two or three cuttings, yielding in a season from two to four tons of hay per acre. Since it furnishes no late fall or early spring pasture, other grasses or annual pasture crops must be grown in order that the farmer may supply continuous grazing for his stock.

Bermuda grass may be propagated both from seed and from root-cuttings. The seed is often low in vitality and sprouts so slowly that the young plants are apt to be crowded out by weeds; hence this method of starting Bermuda grass cannot be recommended, except where roots cannot be readily secured. In such cases, the planting should be on a small area to produce plants whose roots may be used for planting larger areas. The seed-bed should be clean, fertile, and well-pulverized. The seed must be sown late in the spring after the danger from freezing is past, and covered very lightly. One pound of seed is sufficient to plant from one fourth to one third of an acre. The seed is expensive, costing from fifty cents to a dollar a pound.

The grass may be propagated most readily and cheaply by transplanting pieces of the sod, about two inches square, at intervals of from one to two feet, in rows three feet apart. It may also be propagated from cuttings of the roots from two to three inches long, planted from six to twelve inches apart, in shallow furrows from three to four feet apart. The roots or the pieces of sod should be covered to a depth of from two to four inches. The space between the rows may be cultivated for a time, or a light seeding of oats or other grain may be planted as a nurse-crop, to be cut for hay or pastured off with cattle. Horses or sheep should not be allowed to graze on the young grass, because they destroy many of the creeping stems and prevent the rapid spread of the grass. Planted as described above, under favorable conditions Bermuda grass will cover most of the intervening space by the close of the season. A similar method may be employed to start lawns, but the soil should receive more careful preparation and the cuttings or the pieces of sod should be planted at closer intervals to insure quick growth and a uniform cover.

Bermuda grass is very persistent and very difficult to eradicate from good soil when climatic conditions favor its growth. Usually, farmers who use it in rotation with other crops do not desire it completely eradicated, but depend upon its roots which are left in the soil to renew the stand of grass after other crops are removed. In Kansas and Oklahoma, Bermuda grass may be completely eradicated if proper methods are used and advantage is taken of the climate, soil, and season. Late fall or winter plowing, which exposes the tender roots to severe freezing, will largely destroy it; or if plowing is done at the approach of a dry season and the roots are dragged to the surface with a harrow or weeder, the grass may be destroyed. If smother-crops are then planted or if the land is planted with inter-tilled crops and given thorough cultivation, very few plants will remain the second season, and these may be exterminated by carefully digging them out.

Bermuda grass seldom produces seed north of Florida and southern California, and where seed is not produced it does not readily spread to fields where it is not planted. In localities where it produces seed abundantly, it spreads everywhere and cannot be controlled.

When it is desired to keep Bermuda pasture more or less permanent, the grass requires renewing occasionally by re-plowing, or by fertilizing, or both. It usually becomes very thick and sod-bound and non-productive after four or five years. In such cases, the grass may be renewed by breaking the sod in the fall and planting winter grain, such as winter-wheat, barley, or oats. The next season, after such grain crop is removed, Bermuda grass will thicken up rapidly and furnish early summer and late fall grazing. The pasture should be fertilized occasionally with barnyard manure, or commercial fertilizers. It is also advisable to use cowpeas or clover in rotation, in order to maintain the supply of soil nitrogen.

Grasses of Doubtful Value, Which are Often Noxious Weeds

There are four well-known grasses, or grass weeds, which ought to be mentioned under this head: Johnson grass; quack-grass; crab-grass; and chess, or cheat. All of these grasses are great pests under certain conditions; yet when properly managed, each of them often makes valuable pasture or hay.

Johnson Grass

Johnson grass (*Sorghum halepense*) is said to be the worst weed in the South; yet it will yield from two to five crops of good hay each year, averaging from one to three tons per acre each cutting. This hay is relatively high in feeding value and is relished by all kinds of stock. The only objection to the grass as a forage crop is the difficulty with which it is controlled or eradicated when once it has become established.

Johnson grass belongs to the sorghum family. It is a perennial and, until the plants are a foot high, closely resembles young cane. It is well supplied with leaves, and often reaches a height of eight or ten feet, though the average height for this hay is from three to six feet. It has an open, branching head, from six to twelve inches long, which produces many seeds. The seed slightly resembles flax and has strong vitality. The plant is usually propagated from the seed, but it may be started by planting the roots. It fills the surface soil with numerous large, creeping root-stocks, which are supplied with latent buds about an inch apart, each of which may produce a new plant.

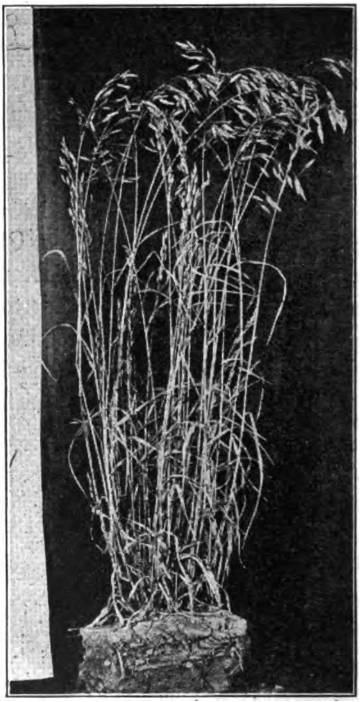

FIG. 34.—Chess (*Bromus secalinus*).

Johnson grass is adapted only to a warm climate. It is a hot-weather plant which can stand much drouth, but produces large yields only with an ample supply of moisture. It starts to grow late in the spring and ceases at the approach of the first cool weather. In the summer it grows rapidly, and it may be cut as often as once a month while the weather remains warm. It is essentially a soiling grass, and does not endure close grazing. The trampling of the stock kills the roots and causes the grass to become thin and patchy. When this grass is used for pasture, it is necessary to plow the pasture occasionally in order to renew the stand of grass.

Johnson grass is a native of western Asia. It was introduced into the United States in 1835, by Governor Means, of South Carolina. A few years later, it was widely distributed throughout the South by William Johnson, of Alabama, from whom it takes its name. It is hardy only in the states south of the fortieth parallel. Even in the southern states the growth in the spring is relatively late and slow. It is not hardy where the frost penetrates the ground to the entire depth of the creeping root-stocks, since these roots are killed as deep as the frost penetrates. The grass usually winter-kills at the Kansas Experiment Station. Even in the southern counties of Kansas there is little fear that this grass may become a pest, since it will be destroyed by severe winters; and destruction may be readily accomplished almost any winter by deep plowing and dragging late in the fall, which exposes the root-stocks of the grass to the winter frosts. Farther south the eradication of the grass becomes a more difficult problem. Persistent destruction of the young grass by cultivation will largely eradicate Johnson grass from a field in a single season. Bulletins giving further information upon this subject may be secured from experiment stations in Oklahoma and in other southern states.

While the Kansas farmer need not fear this grass as a pest, he should exercise care to prevent it from spreading. Spreading may result from distribution of seed, or from the dragging of roots to a new locality. Johnson grass has become so much of a pest in some of the southern states that laws have been passed making the careless spreading of the grass a misdemeanor.

Quack-Grass

Quack-grass (*Agropyrum repens*), also called couch-grass, witch-grass, twitch-grass, etc., is one of the perennial wheat-grasses, and is much more persistent than others of its kind. When once well-started under favorable conditions it spreads rapidly from bud-producing, creeping root-stocks, which branch out in every direction and crowd out all other plants. This grass also propagates freely from the seed.

Quack-grass is a native of Europe. It flourishes best in a moist, temperate climate, in a fertile clay-loam or in black-loam soil. The stems range in height from one to three feet, but the under-growth is thick and the sod formed is tough. The flowering spikes are rather slender, resembling wheat heads. The leaves are of a dark-green shade and are coarse and tough. The stems become woody as the grass approaches maturity. However, when fresh and young, the grass is well-relished by stock and makes good pasture. Where it is not dangerous as a weed-pest, it makes an excellent soil binder for gulleys and embankments. In fertile soil, if renewed by re-plowing and cultivation, it produces large yields of good hay when it is cut in season.

Thus it has some good qualities, but since other more valuable grasses which are not dangerous weeds thrive under the conditions favorable to the growth of quack-grass, the seeding of quack-grass on any farm cannot be recommended. If the grass is accidentally started in a field, the farmer should employ every available means to exterminate it at once. Culture-methods, by which quack-grass may be eradicated from cultivated fields in a year or two, have been discovered and are now in use among northern and eastern farmers. One of these methods is known as the "Crane System," and was discovered and practiced successfully by Mr. P. B. Crane, of Long Lake, Minn. He describes his method in a little book which he has published.[1]

While quack-grass is a dangerous pest in Canada and in the northern and eastern states, it is not very difficult to control in the West and South. However, there is a certain species of grass much like it, known as western wheat-grass (*Agropyron spicatum*), which is a native of the Western Plains. Western wheat-grass is a pest and is difficult to eradicate from fertile, moist soil in eastern and central Kansas. It is, nevertheless, of value for pasture and may be recommended for seeding in western Kansas, though at this time seed is difficult to obtain, since the grass has not been domesticated. Western wheat-grass is well worthy of cultivation and improvement.

Chess

Chess, or cheat (*Bromus secalinus*) is one of the brome-grasses; but instead of having great economic value, like *Bromus inermis*, it is a foul weed that is very troublesome in the winter-wheat growing states. This is the common cheat-of-wheat, so-called, perhaps, because it often deceives the farmer and cheats him out of a crop. It grows very much like winter wheat, growing from seed in the fall, living through the winter, starting again early in the spring, and maturing a little earlier than the wheat. The ripe seed shatters, thus re-seeding the ground for the next crop. If the wheat is checked or killed by winter freezing, chess may take its place and give the farmer a crop of cheat instead of wheat. So often has this occurred that, until recently, many farmers believed that wheat turned into cheat. Since this grass is a winter annual, growing each fall from seed matured that same season, it is readily controlled by a rotation of crops which includes corn or other inter-tilled crops. Then if the seed-wheat, or other seed-grain is carefully graded, a chess-free crop may be secured.

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[1] Published by Webb Publishing Co., Minneapolis, Minn.
The Vermont Experiment Station has recently published Bulletin No. 149, "A Practical Method of Killing Quack-Grass."

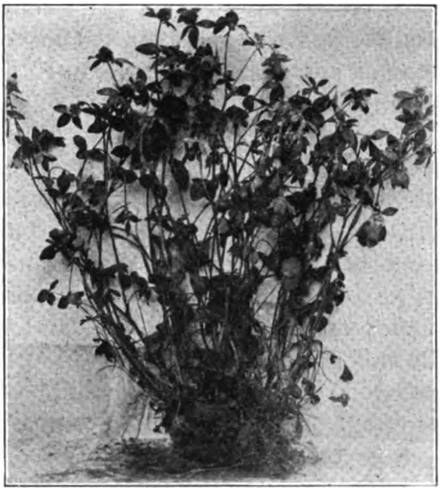

FIG. 35.—Medium Red clover.

This grass has some value for winter and early spring pasture, and may make fair hay if cut before it blooms. But other grasses are to be preferred for such use. As a matter of fact, chess is often found as an adulterant of orchard-grass, meadow fescue, and *Bromus inermis* seed. Its presence in grass seed is doubtless often an accident, due to the presence of the chess in the meadow, except the first year after seeding. It is readily destroyed by mowing before it seeds.

Crab-Grass

Crab-grass (*Panicum sanguinale*) is really a species of millet, belonging to the same genus as Japanese barn-yard grass (*Panicum crusgali*). It is an annual which grows best in the hottest weather. Its flowering spikelet bears some resemblance to the claw of a crab, hence the name. The grass spreads rapidly because the stems partly recline and tend to root at each joint. It matures quickly and seeds abundantly. The seeds may retain vitality for several years when buried deep in the soil without favorable conditions for germination.

Crab-grass is a great pest in corn and in other inter-tilled crops, for the quick-rooting, intertwining stems make it difficult to destroy by cultivation. The fact, also, that the seed germinates late in the season, after the ordinary cultivation of corn ceases, makes it a very difficult weed to eradicate. If rains follow the harvest, this grass springs up quickly in grain-stubble fields and grows rapidly, maturing seed in a few weeks. In such cases, it may be cut for hay or used for pasture. It is best controlled by planting late smothering crops, such as sowed cane, or Kafir, or by rotation of such crops as will require late cultivation or a partial summer fallow. A season or two of thorough, late cultivation will clear the land of this pest.

Crab-grass has some value both for hay and for pasture, but it is seldom used for this purpose. Sometimes, if a crop of it is produced, the farmer attempts to plow it under before it seeds and then it furnishes some green-manure. More often, the mature crab-grass is burned off in preparing the land for planting the next crop. While this grass may have some local economic value, it is a troublesome weed in Kansas and should be dealt with strenuously.

Clover

It is not the purpose in this bulletin to treat the subject of clover fully. The term "clover" includes a number of species of several genera of the *Leguminosæ* family, which, as a group, are excellent forage crops and unequaled as soil fertilizers. Botanically, the true clovers belong to the genus *Trifolium*, plants with leaves divided into three leaflets and flowers collected in cone-shaped spikes or rounded heads. Several valuable cultivated species are medium red clover (*Trifolium pratense*), mammoth clover (*Trifolium magnum*), Alsike clover (*Trifolium hybridum*), small white clover (*Trifolium repens*), and crimson clover (*Trifolium incarnatum*). Agriculturally, several other valuable leguminous plants are classed as clovers; one of the most valuable of these is alfalfa (*Medicago sativa*). Other species which have more or less value are Bokhara, or sweet, clover (*Melilotus alba*), Japan clover (*Sespedeza striata*), and burr clover (*Medicago denticulata*).

All the plants of the clover family have the power to take from the soil the nitrogen required for their growth. They do this by means of bacteria which live in little tubercles or nodules on the clover roots. Thus clover may not only produce large yields of valuable forage very rich in that most important food constituent, protein, without drawing on the nitrogen of the soil, but by its growth of roots and by the accumulation of nitrogen compounds in the tubercles and in the roots, clover actually increases the supply of available nitrogen in the soil, thus enriching the soil. However, the long and continuous growing of clover may largely exhaust the supply of mineral plant-food elements in the soil, causing the soil to become "clover sick" or unbalanced in plant-food supply and hence non-productive of all other crops as well as of clover.

The Common Field Clovers

Many of the general principles as related to seed-bed preparation, seeding methods, making hay, etc., which apply to grasses, apply equally well to clovers. There are, however, slight differences in the time and methods of seeding best adapted to certain varieties of clover, as compared with grasses. For instance, in this climate, medium red, mammoth, and Alsike clovers are not safely seeded in the fall, since the fall-seeded clover is very likely to winter-kill. Clover should be seeded early in the spring, or it may be fairly successful if planted in well-prepared soil in the late summer. In Kansas, it is the usual custom to seed clover early in the spring with a nurse-crop of small grain, as clover succeeds better, perhaps, than most grasses when sown with a nurse-crop. However, it will usually succeed best when sown alone.

Clover should always be mowed or pastured in the fall of its first year; this is necessary in order to prevent it from seeding, since if the plants produce seed they are apt to die during the first winter, leaving a thin, patchy stand the next season when the largest crop should be produced. Of the common clovers, medium red, and mammoth are ordinarily biennials, the plants dying the second year, or after producing seed. White clover and Alsike are more nearly perennial, though the stand of Alsike clover gradually becomes thinner and is seldom thick enough to leave after the third year.

Unless grown for seed production, clover should be sown usually in combination with grasses both for pasture and for meadow. If the clover is not pastured too closely or cut too frequently, it will re-seed itself sufficiently to maintain a partial stand for a long period, or by scattering a little new seed occasion-

ally early in the spring, clover may be continued indefinitely. In fact, it is advisable, where clover succeeds, to scatter clover seed occasionally in permanent pastures, or in meadows where it will act as a fertilizer of the soil.

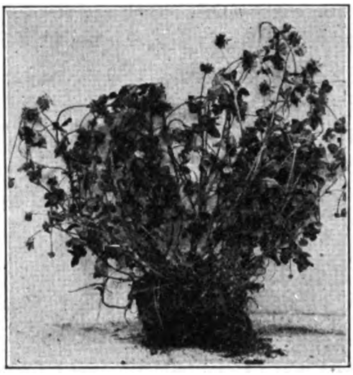

FIG. 36.—Alsike clover.

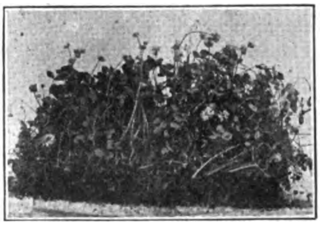

FIG. 37.—Common White clover.

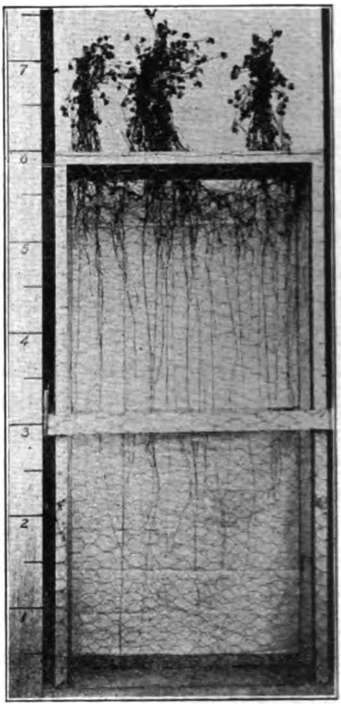

FIG. 38.—Medium Red clover roots. Sample taken August 19, 1904, being the second crop of clover for that season. This clover was seeded in the spring of 1903.

Common clovers are not so well adapted to Kansas conditions as is alfalfa, except perhaps in the eastern and southeastern part of the State. Clover cannot be recommended for seeding in middle and western Kansas except under special conditions, as on low, well-watered land or on land too wet to grow alfalfa.

MEDIUM RED CLOVER

For producing valuable forage and enriching the soil, medium red clover exceeds the other varieties. It produces regularly two or more cuttings each season, while other varieties usually produce one cutting. It furnishes early and late pasture. It is a surer seed producer and is better adapted to ordinary conditions

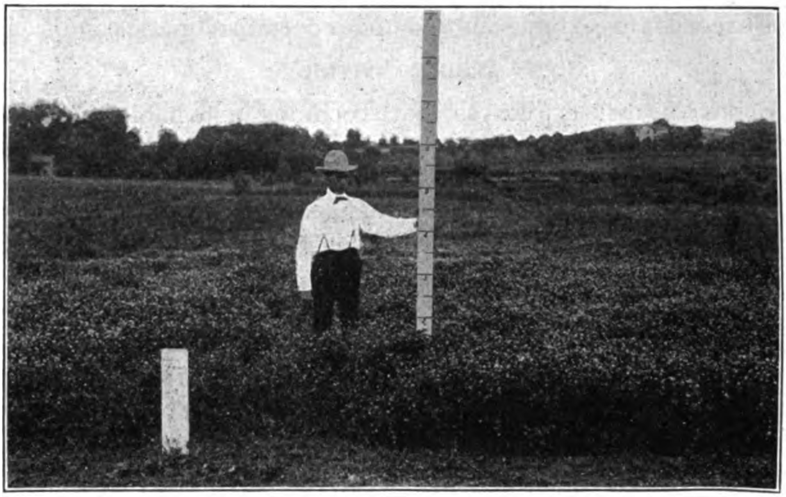

FIG. 39.—Variety plot of Alsike clover, June 23, 1904. Photo taken just before cutting for hay. Seeded in the spring of 1903.

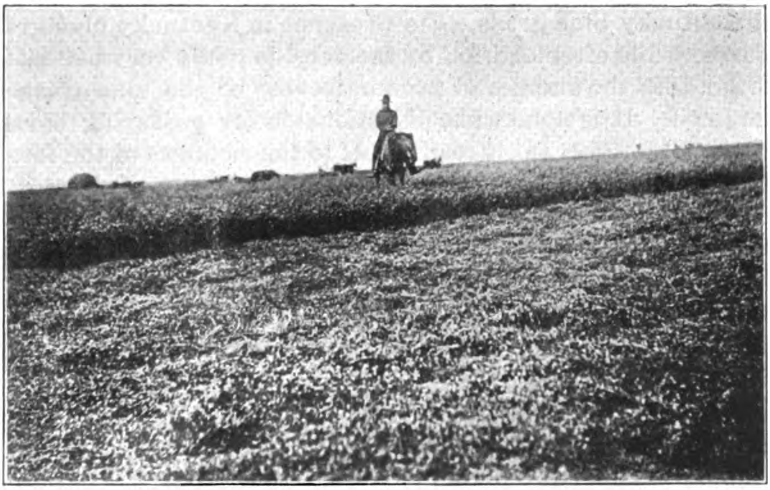

FIG. 40.—A typical Kansas alfalfa field.

than either the Alsike or the mammoth varieties. As a soil improver it is rarely excelled by any other legume when used in regular rotation, except that alfalfa or mammoth clover may perhaps exceed it in certain soils and under certain climatic conditions.

ALSIKE CLOVER

Alsike clover is less coarse, more reclining in its habit of growth, and more leafy than medium clover. It is also more hardy and better adapted to wet or poorly drained land. Because of these characteristics it is preferred to the medium or mammoth clover for pasture. White clover is superior to Alsike as a permanent pasture plant.

MAMMOTH CLOVER

Mammoth clover is larger and coarser than medium red clover. Its roots are larger and extend deeper into the sub-soil. As a soil improver it may be somewhat superior to the other clovers, especially on heavy land with clay sub-soil. For hay it is inferior to Alsike or medium clover because of its coarse, stemmy character; and it is also less valuable for pasture, since it starts later in the spring and does not make so rapid a growth after cutting as do the other clovers.

WHITE CLOVER

White clover, the hardiest and most widely distributed of all clovers, is peculiarly valuable as a pasture plant when combined with Kentucky blue-grass. Its presence in Kentucky blue-grass pastures, while often decried by farmers, is really very necessary in order that the stand and productiveness of the blue grass be maintained. It is somewhat objectionable for pasturing horses, causing slobbering; yet it really adds to the richness of the forage and its presence increases the amount and improves the quality of the grazing, due to its fertilizing effect on the soil. Where it thrives best, white clover is unexcelled as a honey producer, which is another reason for maintaining it in pastures and lawns.

Annual Clovers

CRIMSON CLOVER

Crimson clover is one of the more important annual clovers. It is adapted to a moist, mild climate. The usual practice is to seed it in the summer or early fall. It then grows late into the autumn, furnishing fall and winter pasture. It starts early in the spring and may be used for pasture or soiling, cut for hay, or plowed under for green manure. Where it succeeds well, it is a valuable soil fertilizer. It is better adapted to soils low in fertility than are most other legumes.

It is doubtful whether crimson clover may be profitably grown in Kansas, for it has not succeeded very well at the Kansas Experiment Station. Seeded in the spring, it makes little growth and it is not hardy when seeded in the fall. In the southern counties of the State it should give better results and may be recommended for trial by early fall seeding.

JAPAN CLOVER

Japan clover is one of the hardiest plants of the clover family for a warm climate. It is well adapted to conditions in the southern states, but it is not hardy in the colder climate of the northern states. In recent years, it has been introduced into parts of southern Kansas, where it appears to be quite hardy, growing and thriving in the native prairie pastures to such an extent that some farmers fear it will crowd out the grasses. However, Japan clover is more likely to invigorate the growth of the grass by increasing the fertility of the soil. It also adds to the amount and richness of the grazing.

Japan clover retains its hold on the soil by re-seeding itself each year. It starts very late in the spring and is checked by the first autumn frosts; yet, where the climate is warm enough, when once established it is very persistent, and its power of self-propagation in the South nearly equals that of white clover in the North.

Japan clover is usually seeded in the spring. It may be sown in the fall in the southern states; but in Kansas, late spring seeding is preferable on account of the tender nature of the young plants, which are likely to be destroyed by a late spring frost. Perhaps the only practical use for Japan clover in this State is for pasture. In seeding the pasture early spring discing previous to seeding and light harrowing after seeding will greatly assist in securing a good stand. When well started under conditions which allow its growth, it will continue to propagate itself unless grazed so closely as to prevent it from producing seed. Late fall or early spring discing and harrowing will favor the starting of the young clover and may also increase the growth of other grasses.

SWEET CLOVER

The value of sweet clover is variously estimated by different farmers in different parts of the country. By some it is considered an objectionable weed of no value, while others claim it is equal to alfalfa as a forage crop. This difference in opinion is largely due to the different methods of handling the crop. If sweet clover is allowed to grow large and coarse, its natural condition as a roadside weed, it has little value. When seeded thickly in cultivated fields and pastured closely or mowed early, it makes good pasture or yields a fair quality of hay of high nutritive value. Its worst characteristic is its bitter taste, to which live stock must become accustomed before they will eat it readily. It appears, however, that stock learn to like sweet clover, and will thrive on it. Sweet clover is also valuable for bee pasture, producing much honey of excellent quality.

Perhaps it is most valuable as a soil fertilizer when grown in rotation with other crops. It is adapted to poor soil and is a good crop to precede alfalfa in order to put the soil in good tilth and to provide bacteria for starting the young alfalfa. Sweet clover bacteria will also live and thrive on alfalfa roots and insure the successful growing of alfalfa in soils which are lacking in alfalfa bacteria.

In the southern states, sweet clover should be seeded in the spring, but in Kansas and in states farther south, late summer or early fall seeding should be preferred. If sown too late in the fall the young plants are likely to winter-kill. When the plant produces seed it dies, but by pasturing or frequent cutting, sweet clover may be made to continue its growth during the summer. If allowed to mature seed it readily re-seeds itself and maintains its stand. As a weed, it is often so persistent that many farmers have supposed the plant to be perennial and difficult to eradicate; but this is not true. A single year's thorough cultivation of the soil will practically clear the land of sweet clover, and it may be largely destroyed by mowing when the plants are in full bloom.

Sweet clover may often be advantageously sown in old pastures and on rough land, where, when it becomes established, it will add much to the amount of grazing. By improving the fertility of the soil, it will cause a renewed growth of other grasses.

There are two common varieties, the white-flowered and the yellow-flowered. The white-flowered variety is a ranker, coarser grower and perhaps a better fertilizer, though it may have less value for hay or pasture. The yellow-flowered sweet clover is less coarse, more reclining in its habit of growth and more leafy than is the other variety. It would seem to be the better variety for pasture and perhaps for hay. It is not so widely distributed as the white-flowered variety and may not be so hardy. There seems to be no record of comparative tests of these varieties to prove their relative value.

BURR CLOVER

Burr clover is not hardy in Kansas, but succeeds well farther south. It is a fall annual or biennial, starting early in the autumn and, in a mild climate, growing late in the winter. It matures its seed early the next spring, ripening in May. It has considerable value for winter pasture in the southwestern states, but its particular value lies in its adaptability as a catch-crop, or fertilizer.

Conclusion

In this bulletin I have presented certain experimental data which have been secured during the past eight years by myself and my assistants in the Department of Agronomy at the Kansas State Agricultural Experiment Station. I have also attempted to give to my fellow farmers the benefit of my observation, investigation, and experience along this line, carefully summarized in the general information and suggestions published in these pages. I hope and believe that this bulletin will do much good.

Few of us have even begun to appreciate the value of grass to permanent and successful agriculture. Without grass and its allies, clover and alfalfa, profitable agriculture would soon cease. As a modern agricultural writer puts it: "No grass, no cattle; no cattle, no manure; no manure, no grass," and we may truthfully add, "no crops." We have the saying, "more truth than poetry." This bulletin is not poetical, but there is poetry in grass and there is truth in poetry, and as a tribute to grass and also to one of Kansas' greatest sons, John J. Ingalls, I wish to conclude this bulletin by quoting Mr. Ingalls' magnificent prose-poem:

"Grass is the forgiveness of Nature—her constant benediction. Fields trampled with battle, saturated with blood, torn with the ruts of cannon, grow green again with grass, and carnage is forgotten. Streets abandoned by traffic become grass-grown like rural lanes, and obliterated. Forests decay, harvests perish, flowers vanish, but grass is immortal. Beleaguered by the seven hosts of winter, it withdraws into the impregnable fortresses of its subterranean vitality and emerges upon the first solicitation of spring. Sown by the winds, by the wandering birds, propagated by the subtle horticulture of the elements, which are its ministers and servants, it softens the nude outline of the world. Its tenacious fibers hold the earth in its place and prevent its soluble components from washing into the wasting sea. It invades the solitudes of the deserts, climbs the inaccessible slopes and forbidden pinnacles of mountains, modifies climates, and determines the history, character, and destiny of nations. Unobtrusive and patient, it has immortal vigor and aggression. Banished from the thoroughfare and the field, it bides its time to return, and when vigilance is relaxed, or the dynasty has perished, it silently resumes the throne from which it has been expelled, but which it never abdicates. It bears no blazonry of bloom to charm the senses with fragrance or splendor, but its homely hue is more enchanting than the lily or the rose. It yields no fruit in earth or air, and yet, should its harvest fail for a single year, famine would depopulate the world."

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